University of Cape Town, School of Economics

Regime Changes in Monetary Policy

Ph.D. Thesis

by

Samuel Addo

Thesis submitted for the Degree of Doctor of Philosophy in Economics

June 2017

Advisors: Prof. Mark Ellyne and Dr Lebogang Mateane

Regime Changes in Monetary Policy - Samuel Addo, June, 2017

Abstract

This thesis consists of six chapters of which chapters one and two provide the introduction and a brief review of policy regimes in South Africa. Each of the three chapters that follow has its own structure and method. Chapter six concludes the thesis. The chapters share a common theme of understanding the effects of policy regime changes in stabilising inflation and output dynamics in emerging economies with reference to the South African economy. This thesis's theme is premised on the debate that policy rate setting better describes the conduct of monetary policy and helps stabilise inflation and output. There is, however, no consensus on the appropriate policy regime and the specification of a policy rule that is universal for all economies.

Chapter three establishes whether central bank preferences are related to governors' tenures when there is a change in policy regime. A time-varying parameter approach that allows the policy preferences to vary over the sample period is used. The results show that the policy parameters exhibit significant changes and that the South African Reserve Bank placed more weight on output relative to inflation over the period 2000 and 2007. The dynamic responses of output and inflation under different central bank governors show different outcomes because of changes in central bank policy preferences and not necessarily different governors at the central bank.

The effects of policy switches on macroeconomic performance using a regime-switching small open economy dynamic stochastic general equilibrium model is investigated in chapter four. The novelty of this chapter is found in the structural model, where the primary commodity export sector follows a regime shock process that affect the policy parameters is allowed. The results suggest that an unexpected monetary policy shock and its variances account for a smaller proportion of macroeconomic fluctuations in the South African economy compared to external shocks and its variances in the form of exports, import cost inflation, risk premia,

preference and technology changes.

Chapter five consists of an investigation into central bank credibility by simulating a Markov-switching Bayesian vector autoregression model with time-varying transition probabilities. This is based on changes in monetary policy leading to clear policy goals. The findings suggest that the policy authority was credible over the period 2003 to 2007 and over the period 2010 until 2016. However, policy switched to a low credibility regime over the period 1990 to 1999 and in 2008. It is found that a positive yet unexpected change to credibility leads to a reduction in policy rate which leads to a decrease in inflation. The conclusion indicates that credibility is an important instrument that helps policy authority to conduct efficient monetary policy in stabilising inflation and output.

Declaration

I, Samuel Addo, certify that this thesis I present for examination for a Ph.D. in Economics degree at the Doctoral Degrees Board Office through the School of Economics, University of Cape Town is my own original work other than where I have cited that it is the work of others. Further, it has not been previously presented for a degree at any university.

Acknowledgements

I wish to express my gratitude to Prof. Mark Ellyne and Dr Lebogang Mateane for their valuable guidance and timely intervention to complete this thesis. Any time I reflect on this adventure I will remember their patience and the love they exhibited towards me in the course of this thesis. I thank Dr Amos Carl Peters who was outstanding in helping me to shape my vague ideas into a research project.

I would like to thank uniBank Ghana Limited for giving me the opportunity to pursue a doctoral degree. In particular, Dr Kwabena Duffuor II, the Chief Executive Officer, Ekow Nyarko-Dennis, the Deputy Chief Executive Officer and Paul Appiah-Gyasi, former Head of Finance, all of the uniBank Ghana Limited, are thanked for their encouragement and financial support.

Life in Cape Town would have not been enjoyable without all the wonderful friends that I met along the way. I thank especially Eliud Moyi and James Gichuki, who stood by me side by side at all times and shared jokes, food and drinks and excellent Bible expositions. Indeed, they have been great friends and I thank them. Eliud, especially, is thanked for his patience and for reading my drafts with good feedback.

My greatest treasures, Adom, Oheneba and Kobby, are thanked for their sacrifice whilst I was away. I thank my family for always being there for me with their prayers, good counsel and the comfort they always provide.

I dedicate this thesis to my wife, Nana Adwoa Serwaa Addo, for all the sacrifices she made and her daily phone calls to me in Cape Town.

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Chapter 1

Introduction

1.1 Background

Monetary policy regimes are analysed by macroeconomists to understand how central banks change monetary policy in response to the economic fundamentals that are output growth, inflation and the exchange rate. Further, policy regimes provide a basis for forecasting changes in a central bank's reaction function and also help in evaluating a central bank's monetary policy strategy. As documented by McCallum (1999), some of the pioneers of studies on monetary policy regime changes are Wicksell (1898) and Fisher (1920). For example, Wicksell (1898) proposes that interest rates should change with changes in prices, whereas Fisher (1920) revisits the quantity theory of money and suggests that price stability should be part of monetary policy objectives because a free market economy is characterised by the need to stabilise the economy.[1] Among others, Bordo and Schwartz (1999), Taylor (1999) and McCallum (2000) provide an overview of monetary policy regime changes.

Money supply was the main policy instrument in the 1980s, yet the velocity of money supply was unstable.[2] In the early 1990s a popular monetary policy

[1]See also the Swedish price level targeting in the 1930s proposed by Cassel (1930) and Friedman (1953) constant money growth rate used in the 1960s.

[2]The money supply instrument is defined as growth rate of money supply equals desired

regime, the so called 'Taylor rule' was proposed by Taylor (1993).[3] The Taylor rule has attracted much research attention from policy authorities and academic economists in Australia, Canada, Chile, New Zealand, South Africa, the United Kingdom (U.K.), the United States (U.S.), etc. Although empirical literature shows that the Taylor rule characterises monetary policy behaviour in a number of advanced and emerging economies, no consensus has emerged on the appropriate policy regime and a single specification of the Taylor rule for all economies (see Woodford (2015), Taylor (2014) and McCallum (2015)). Therefore, this provides a motivation to examine monetary policy regime changes in emerging economies with reference to the South African economy.

The choice of South Africa for this thesis is because it has consistent and clean time series data that can provide accurate and solid results for the issues under review compared to Brazil, Russia, India and China (BRICS). These countries have limited time series data and the quality of their series mostly starts from 2000. Therefore, a study of this nature has to minimise the trade-off between the model, methods and data that are most appropriate to generate reliable estimates. Similarly, South Africa is part of a larger group of the emerging economies of the BRICS nations and sub-Saharan Africa that represents a potential experimental laboratory for monetary policy regime analysis. This evaluation may help in an understanding of the importance of policy regime changes after adoption of inflation targeting regime over a decade and a half in emerging economies. Moreover, South Africa has a long tradition of monetary policy practice and central bank independence similar to the U.K., U.S. and elsewhere. The chronology of monetary practice includes the efficient reintroduction of the gold standard in 1925, the adoption of the Bretton Woods agreement in 1939, monetary aggregates regime in 1986 and the adoption of an inflation targeting regime in February 2000 until

output growth rate plus the target inflation rate.

[3]This means that the nominal interest rate is set to the equilibrium interest rate plus a weighted average of the real GDP gap and a four-quarter moving average of actual GDP deflator less target inflation.

present (see Rossouw (2010) for more details).

In South Africa, the empirical literature on monetary policy regime changes is extensive—with mixed results. Similarly, the analysis of the behaviour of the South African Reserve Bank (henceforth SARB) policy decisions are confined to traditional econometrics techniques such as sub-sample and generalised method of moments (GMM), which are too weak to capture the changing dynamics of the economy.[4] This thesis complements the existing research by using an econometric framework that allows for the capture the possibility of changes in policy preferences, regime switches in policy and central bank credibility in the context of monetary policy regime changes.

1.2 Focus and Structure

The focus of this thesis is mainly on the following aspects: first, the investigation of policy regime changes and central bank preferences to understand whether governors' tenures are linked to central bank preferences over time. Although there is much literature on monetary policy regime changes, few studies employ a time-varying parameter approach to examine whether policy authorities preferences change over time which may be influenced by the changing economic environment. Secondly, a Markov-switching rational expectations model is employed to assess sources of macroeconomic fluctuations in the South African economy as a result of policy regime switches. In Markov switching models, a subset of the parameters or the full model parameters change over time and private agents are aware of the probability of these changes occuring and incorporate them in their decision-making in a way that is different from constant dynamic stochastic general equilibrium models. Thirdly, central bank credibility is studied before and after a regime change to understand how these changes impact on monetary authorities' credibility. Given this, credibility is considered as to whether policy

[4]See Aron and Muellbauer (2002), Ortiz and Sturzenegger (2007), Alpanda et al. (2010), Naraidoo and Paya (2012) and Peters (2016), for some of the traditional econometric studies.

authority says what it does and does what it says. This thesis, therefore, does not examine which policy targeting rule variables or measures of credibility indicators are suitable.

The thesis is structured along the following lines. Chapter one considers the background, focus and structure of the thesis. Chapter two reviews monetary policy regimes in South Africa to serve as a foundation for the empirical estimations. In chapter three, monetary policy regimes and the changing behaviour of central banks are analysed. Individual governors' tenures are also examined to determine whether they are linked to central banks' model parameters. To analyse monetary policy regimes across time, a time-varying parameter approach is used with the aim of revealing if and how central bank's policy settings have changed as a result of the adoption of inflation targeting regime without splitting the sample.

In chapter four, monetary policy regime shifts and evolution of macroeconomic performance in a small open economy are estimated using a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) approach. This allows for the capture of parameter instability as a result of changes in policy regimes and structural breaks in macroeconomic data. This will help determine the sources of changes that have contributed to low volatility in inflation and output. Chapter five examines central bank credibility to determine the transmission mechanism of credibility on monetary policy and its effects on inflation and output stability. In this sense, a Markov-switching Bayesian vector autoregressive model with time-varying transition probabilities method is used to reveal how credibility evolves. The final chapter concludes with a brief summary of the thesis themes and provides direction for future research.

Chapter 2

Overview of Monetary Policy Regimes in South Africa

2.1 Background

This chapter surveys monetary policy regimes in South Africa to provide insight into how the policy authority has responded to changing domestic and global economic conditions and sets the basics to tie in the empirical estimations in the subsequent chapters.

Historically, there have been four main monetary policy regimes since the establishment of the South African Reserve Bank on 30 June, 1921. These are the gold exchange standard regime—popularly known as the gold standard between 1925 and 1932, the Bretton Woods arrangement—also known as the gold dollar standard between 1939 and 1979, the monetary aggregates regime from 1986 to 1999, and the present regime of inflation targeting.

Inflation was low and stable during the gold standard regime. However, the conduct of monetary policy lost credibility following the U.S. stock market crash in 1929 and World War II. This resulted in large capital outflows from the South African economy that led to a slowdown in domestic economic activity, setting the stage for the adoption of the Bretton Woods agreement regime. Under the

Bretton Woods system, the primary policy goal was an adjustable-peg exchange rate, whereas gold was tied indirectly to the policy objective.

Although this period recorded high real Gross Domestic Product (GDP) growth compared to the gold exchange standard regime, it was short lived as a result of a weak credible policy rule. Therefore, in the early 1960s, the South African economy witnessed a persistent upward inflation trajectory that directed the policy authority towards inflation stability (see Rossouw (2010)). The SARB introduced a number of monetary policy measures to curb the rising inflation trajectory. This included restrictions on foreign direct investment and the repatriation of domestic investment by non-residents, and direct credit controls, but were jettisoned in 1979 owing to its ineffectiveness.

Given that this thesis focuses on monetary aggregates and inflation targeting regimes, the next section provides an account of the two regimes and its effects on inflation and output growth. In section three, the SARB governors' policies and economic performance are reviewed. The final section concludes.

2.2 Monetary Policy Regimes since 1980

This section provides a brief review of monetary aggregates and inflation targeting regimes in South Africa. Detailed overviews of the two policy regimes are provided in Gidlow (1995) and Aron and Muellbauer (2007). Prior to an inflation targeting regime, the governors of the SARB and other officials with the Bank had the ultimate responsibility for policy decision, but the decision process was not transparent between 1980 to 1999. The SARB anchored monetary policy decisions on money growth targets and set flexible money growth targets that were announced each year. The SARB resorted to a monetary condition index towards the end of the 1990s (Stals (1997)).

Following the adoption of a monetary aggregates targeting, policy authority pursued a market-oriented policy. Thus policy authority abandonded direct credit controls, and from 1994 gradually removed the exchange rate controls; and the bank rate was replaced with the repurchase (repo) rate in 1998. This was, however, due to the effects of financial innovations in the early 1980s and capital account liberalisation in 1995 that reduced the credibility of monetary aggregates regime as a policy rule. Way back in 1996, the SARB carried out implicit inflation targeting with a target range of 1 to 5 per cent. In 1998, the Bank was not prepared to adopt an explicit inflation target approach due to weak forecasting models, among others.

In February 2000, the SARB officially announced inflation targeting as a new monetary policy regime. In accordance with the 1996 Constitution (Act No. 8, 1996) and the SARB Act (Act No. 90, 1989), an inflation target is set by the Finance Minister in consultation with the SARB. Nevertheless, the policy instrument required to stabilise the economy is within the control of the SARB. Policy authority follows a flexible inflation target range of 3 to 6 per cent.

At the inception of the inflation targeting regime, the SARB target was the consumer price index excluding mortgage interest cost, that is, the CPIX until 2008. However, due to the rebasing of the consumer basket by Statistics South Africa, it changed from CPIX to overall consumer price index (CPI) from January 2009, but retains the target range. In addition to this, there has been improved accountability, transparancy, credibility and forecasting as a result of an inflation targeting regime. Similarly, the policy rate is set by the Monetary Policy Committee that currently consists of six members who meet six times a year.

Given that its aim is to assess policy regimes from 1980, this thesis examines whether an inflation targeting regime plays a significant role in stablising inflation and output. Table 2.1 presents economic performance by regimes over the period 1986 and 2016. The summary statistics in Table 2.1 show that inflation targeting regime is associated with low inflation averaging 5.81 per cent relative to average inflation of 12.26 per cent over the monetary aggregates regime. A similar trend is exhibited regarding real GDP and policy rate, with average rates of 3.01 and 8.16 per cent over an inflation targeting regime compared to 1.82 and 14.46 per

Table 2.1: Macroeconomic performance by regimes

	CPI Inf		Real GDP		Policy Rate	
	Regime1	Regime 2	Regime1	Regime2	Regime1	Regime2
Summary statistics						
Mean (%)	12.26	5.81	1.82	3.01	14.46	8.16
Median	13.08	5.67	2.08	2.93	15.00	7.50
Standard Deviation	3.81	2.60	2.82	1.91	3.72	2.64
Observations	80	67	80	67	80	67
Stochastic test						
Variance ratio	1.11	1.57	1.53	1.47	1.42	1.61
$Z_{stat.}$	1.02	2.93	3.14	2.45	2.96	3.08
$Prob_{value}$	0.309	0.002	0.002	0.014	0.003	0.002
AR(1) regression						
Parameter	0.56	0.46	0.19	0.55	0.88	0.95
Std. error	0.09	0.11	0.11	0.10	0.04	0.03
$t_{stat.}$	5.81	4.11	1.61	5.20	20.64	28.53

Note: Quarterly data from 1986 to 2016. Regime 1 represents monetary aggregates targeting regime (1986–1999), Regime 2 represents inflation targeting regime (2000–2016). In the AR(1) regression, a log difference of real GDP and CPI is used. Source: SARB, IMF and Author's calculation April 17, 2017

cent respectively over the monetary aggregates targeting regime. The standard deviation is used to measure the variability of inflation, real GDP and policy rate. Table 2.1 shows that inflation targeting regime is associated with a low variability in inflation, real GDP and policy rate compared to monetary aggregates regime.

The stochastic test is used to ascertain the predictability of the key macroeconomic variables in the two regimes. The variance ratio shows that the series exhibit substantial nonstationarity in both regimes because all the ratios are greater that one. This implies that the series in the model are economical essential in explaining large macroeconomic fluctuations. However, the $Z_{statistics}$ shows that CPI inflation is more predictable in an inflation targeting regime relative to the monetary aggregates targeting regime. The $Prob_{value}$ of the stochastic test indicates that inflation is persistent at a 5 per cent marginal significance level in inflation targeting regime, while inflation ceases at 5 per cent significance level in a monetary aggregates regime. Although the autoregressive model of order one AR(1) estimates show that during the two regimes, policy rate and CPI inflation parameters are positive and persistent, real GDP is not persistent even at 10 per cent significance level in the monetary aggregates regime.

The evidence from Table 2.1 suggests that an inflation targeting regime stabilises inflation and output relative to a monetary aggregates regime. This is consistent with the view that more vigorous attention to inflation stability on the part of central banks around the globle in the past three decades is responsible for these changes. This cannot, however, be conclusive evidence as an understanding of the dynamics of policy regime changes on economic performance is more complicated than what these simple estimates suggest.

2.3 Governors' Policies and Economic Performance

The governors are evaluated in relation to their policy objectives and the Bank's key macroeconomic outcomes. In terms of governors, the SARB has had four governors of which three governors served approximately ten–year period each, from 1981 to 2009. These are De Kock from January 1, 1981 to August 7, 1989; Stals August 8, 1989 and August 7, 1999; Mboweni August 8, 1999 to November 8, 2009 and Marcus from November 9, 2009 to November 8, 2014 (see Rossouw (2010) and Gidlow (2011)).

Under the governorship of De Kock, monetary policy was characterised by a discretionary policy with price stability as one of the Bank's policy objectives. The policy authority did not focus only on price stability but also on a stable output growth and the balance of payments management. To achieve these policy objectives, the SARB used monetary aggregates as an intermediate target to influence interest rates. The SARB, therefore, allowed the market to function and adopted broad market base instruments to stimulate the economy. These include open market operations, money market discounting policies, the purchase and sale of foreign exchange and public debt management.

Due to the SARB's broad policy objectives, monetary policy was characterised as one of economic policies in the country similar to agricultural, industrial, labour and fiscal policies.[1] In the long run, the SARB did not evisage trade-off between its broad policy objectives but the Bank recognised this in the short run. Thus conflict could arise either between inflation and output growth or inflation and the balance of payments management. Therefore, the SARB understood that policy could change depending on the business cycle phase that the domestic and global economy experienced, such as job creation and gold price shocks. Discretionary policy was constrained by lack of central bank independence, a weak balance of payments position and high inflation in the 1980s as well as the global financial pressures.

Under Stals's governorship, the guiding policy principle was stable monetary policy as a precondition for sustainable economic growth in the long run. This, and the new mandate of the SARB Act (Act No. 90, 1989), influenced the Bank's policy objective of low price stability with a goal to safegard the value of the South African currency. Although the SARB did not target inflation explicitly, its objective was to bring inflation to the levels of its major trading partners.

During Stals's tenure, monetary policy was mainly used to stabilise inflation relative to De Kock's tenure, where monetary policy had multiple objectives. The SARB used the interest rate as a policy variable and adopted direct and indirect instruments for controlling the economy. The direct instruments include the temporary suspension of market forces to ensure that financial markets adhered to lay down rules such as minimum and maximum levels of lending and borrowing; and exchange control regulations. The indirect instruments include central bank credit to commercial banks, open market operations and the purchase and sale of

[1] See, *Commission of Inquiry into the Monetary System and Policy in South Africa; Final Report (1985).*

foreign currency in the spot and forward foreign exchange market.

This benefited the economy, because at the end of Stals's term, inflation declined from 15.04 per cent in the fourth quarter of 1989 to 3.34 per cent in the third quarter of 1999, in line with South Africa's major trading partners' inflation rate. Similarly, money supply growth declined from 22.3 per cent at the end of 1989 to 10.2 per cent at the end of 1999. Another remarkable event was a successful political transition from apartheid to constitutional democracy in 1994. Despite this, monetary policy faced challenges in the form of excessive depreciation of the South African rand against the U.S. dollar and the British pound sterling. Further, political uncertainty during the tenure of Stals led to economic sanctions and capital outflows that adversely affected the conduct of monetary policy. Similarly, the effects of globalisation did not spare the conduct of monetary policy during Stals's tenure.

Governor Mboweni's policy objective was to maintain low price stability and an economic growth that follows the tenets of inflation targeting framework. This included improved accountability through explicit quantitative inflation targets, increase transparancy and credibility via regular communication with economic agents; and a response to shocks to the domestic economy through forecasting and fiscal dominance independence. During Mboweni's term there were two main constraints to monetary policy. First, the exchange rate shocks coupled with food price hikes in 2002 increased inflation and the policy rate to 12.75 and 13.5 per cent compared with 7.01 and 12 per cent, respectively in 2000. Secondly, the oil price increases from 2006 which peaked in July 2008 and coincided with the global financial crisis in 2008. This increased inflation and the policy rate from 5.53 and 9.00 per cent in 2006 to 13.42 and 12 per cent in 2008, which adversely affected real GDP growth declining to a negative 1.04 per cent in 2009. Despite these events, inflation, policy rate and real GDP growth witnessed considerable stability over the period 1999 to 2009.

In November 2009, Marcus became the central bank governor and continued with the policy of an inflation targeting regime. However, due to the economic recession triggered by the global financial crisis, monetary policy was constrained with economic uncertainty and weak output growth. Policymakers, therefore, adopted countercyclical fiscal policy to boost job creation and economic growth that accounted for high public debt and concerns for fiscal substainability. During this period fiscal deficit as a percentage of GDP increased, with government expenditure moving on an upward trajectory while tax revenue increased marginally. Tax revenue increased from 23.2 per cent of GDP in 2009 to 24.5 per cent of GDP in 2014 and expenditure increased from 24.5 per cent of GDP to 27.8 per cent of GDP over the same period. At the end of 2014, goverment debt stock stood at 47.1 as a percentage of GDP compared to 30.1 percent of GDP in 2009.[2]

This translates into a persistently poor economic performance as against expected real GDP growth rate, as announced in the government budget statements from 2009 to 2014. In 2009, the goverment projected a GDP growth rate of 1.2 per cent. The realised GDP growth rate, however, was negative 1.04 per cent, whereas realised GDP growth outturn was 1.4 per cent as against the projected real GDP growth rate of 2.7 per cent in 2014. This means that policymakers overestimate economic growth to exploit economic agent expectations that the economy is expanding, whereas in reality, it is contracting and experiencing an undesirablely high unemployment rate.

Table 2.2 shows how policy regimes shaped the SARB governors' policy preferences over the period 1981 and 2014. According to Table 2.2, the period under Governor Mboweni is considered as the most stable period for inflation as it is evident from the means and the standard deviations. The governorship of Stals and Marcus were somewhat less stable, while that of De Kock was the most unstable

[2]This can be obtained from South African Reserve Bank Full Quarterly Bulletin No. 278 December 2015

Table 2.2: Economic performance by governors

	CPI				**GDP**				**Policy rate**			
	De Kock	Stals	Mboweni	Marcus	De Kock	Stals	Mboweni	Marcus	De Kock	Stals	Mboweni	Marcus
Summary stat.												
Mean(%)	14.70	10.23	6.03	5.38	1.80	1.31	3.67	2.29	14.10	15.73	9.85	5.57
Median	14.87	9.43	5.94	5.67	2.09	1.18	4.09	2.51	14.25	16.00	9.50	5.50
Std. Dev.	2.34	3.47	3.28	0.90	3.08	2.24	2.08	0.98	3.75	2.32	2.16	0.55
Observations	35	40	41	21	35	40	41	21	35	40	41	21
Stochastic test												
Variance ratio	1.014	1.16	1.67	1.44	1.60	1.53	1.57	1.14	1.46	1.31	1.66	1.20
$Z_{stat.}$	0.08	1.12	3.07	1.81	2.61	2.42	2.26	0.48	2.25	1.40	3.22	1.20
$Prob_{value}$	0.933	0.264	0.002	0.070	0.009	0.015	0.024	0.633	0.025	0.161	0.001	0.232
AR(1) reg.												
Parameter	0.13	0.55	0.52	0.17	-0.16	0.51	0.45	0.41	0.87	0.85	0.92	-0.01
Std. error	0.17	0.15	0.13	0.25	0.17	0.14	0.15	0.22	0.08	0.09	0.07	0.05
$t_{stat.}$	0.75	3.79	3.75	0.69	-0.93	3.58	3.11	1.91	11.35	9.40	13.67	-0.20

Note: Quarterly data from 1981 to 2014. De Kock=data from 1981:Q1 to 1989:Q3, Stals=data from 1989:Q4 to 1999:Q3, Mboweni=data from 1999:Q4 to 2009:Q3 and Marcus=data from 2009:Q4 to 2014:Q4. In the AR(1) regression, we use log difference of real GDP and CPI. Source: SARB, IMF and Author's calculation April 20, 2017.

period for inflation. Regarding real GDP growth rate, Stals's term recorded the lowest and highest variability in output growth, averaging 1.31 per cent and a standard deviation of 2.34 per cent compared to Governor de Kock, with an 1.8 per cent average real output growth. Similarly, under Governor Mboweni, real GDP growth grew by 3.67 per cent on average compared to Governor Marcus with 2.29 per cent average output growth. Similar evidence is found with respect to policy rate, except during the governorship of Marcus, who achieved the lowest policy rate of 5.57 per cent. Although her tenure was five years relative to the remaining three governors who served ten years each.

Under Governor Mboweni, inflation, real GDP growth and policy rate are more likely to be predicted as they are evident of the variance ratio. An important observation is that under Governors de Kock and Stals, it was most unlikely for the inflation and the policy rate to be predicted. Similarly, during Marcus's tenure, policy and real GDP growth rates are unstable and less likely to be forecast. The AR(1) regression in Table 2.2 shows that inflation, real GDP growth and policy rate were persistent under Governors' Mboweni and Stals. This implies that these variables had the tendency to remain near their most recent values and there was a possibility of persistent changes of the variables over time among the governors. Regarding Marcus, the past values of policy rate, inflation and output growth are unable to explain current values at a 5 per cent marginal significance level. This is self–explanatory, because over this period fiscal dominance was at the centre stage of policy relative to monetary policy. This was, however, different under De Kock's tenure, where inflation and real GDP were not persistent at 5 per cent marginal significance level, except the policy rate.

The results clearly support the policy objectives of each of the governors. Although comparing the governors' preferences using the stochastic test and AR(1) estimates, persistence and volatility have declined in some of the variables, and not all have exhibited decline. This ambiguity of results and the sources of decline in the variables that may have happened is of particular interest to researchers.

2.4 Conclusion

Given changes in policy regimes, there are a number of reasons that a regime-switching and time-varying parameter investigation would be suitable for the South African economy. First, monetary policy frameworks across the world have undergone many changes over the last three decades. Secondly, the structural changes of the SARB policy objectives, due to different policy regimes and different governors, can be expected to lead to different central bank policy preferences. Further, governors' policies and economic performances provide interesting dynamics of the governors' preferences for inflation relative to output stability. Since the tenures of the SARB governors have had some consistency over the sample period with varying monetary policy strategies, the thesis will explore whether the changes in the governors' preferences are linked to a central bank policy preferences in chapter three. This thesis may guide an understanding of policy continuity along shifts across different policy regimes.

Chapter 3

Policy Regime Changes and Central Bank Preferences

3.1 Introduction

Central bank preferences are subject to change as a result of changes in monetary policy regimes and any uncertainty about the future state of the economy. Thus the importance that central banks attach to inflation and output and their views on the economic structure may change over time. This results in uncertainty for private agents about future monetary policy conduct, and this uncertainty also affects monetary policy conduct by changing central banks' preferences on inflation and output parameters. For example, Clarida et al. (2000), Cogley and Sargent (2005), Kim and Nelson (2006), Taylor and Williams (2010) and Orphanides and Williams (2011), find that the Federal Reserve Board responded less to inflation volatility in the 1980s compared to the 1970s.

In spite of this, no consensus has emerged on central banks' optimal preferences on inflation and output stability. This has made recent studies such as Boivin et al. (2010), Canova and Ferroni (2012) and Baxa et al. (2014) suggest that further investigation into the following is necessary: first, the effects of monetary policy on inflation trends to identify the key policy risk and performance of inflation targeting regime after the global financial crisis; secondly, determine the factors that influence policy preferences changes to understand the drivers of inflation and output volatility, and finally, incorporate the interaction of financial and macroeconomic variables in modern models due to near zero rates and unconventional monetary policy pursued during the financial crisis.

This chapter focuses on the second debate, that is, factors that influence changes in policy preferences, to understand the dynamics of inflation and output volatility. It is proposed in this chapter that central bank preferences to target variables such as inflation and output vary over time and different preferences of policy authorities may coincide with the tenure of a particular central bank governor. The central bank of interest in this analysis is the South African Reserve Bank. This debate is relevant and current to the SARB's monetary policy regimes decisions, because the South African economy has experienced significant changes in its monetary policy framework over the past three decades. This includes competition in the financial markets in the early 1980s, the monetary aggregates targeting rule first set in 1986, and inflation targeting in 2000. Moreover, the SARB has had four governors, of which three have had consistent terms of approximately ten years each between 1981 and 2009, but each have had varying beliefs about monetary policy conduct.[1] Further, the governors also served under different political regimes, that is, the apartheid era and constitutional democracy. These may influence the weights the governors attach to the policy parameters for inflation and output stability. In particular, the chapter analyses whether changes in central bank preferences are related to governors' tenures, that is, do individual governors exert policy influence in an event of policy regime changes in the context of a time-varying parameter approach?

This chapter relates to other literature that examines changing central banks policy, for example Primiceri (2005), Kim and Nelson (2006), Baxa et al. (2014),

[1]The governors' tenures are De Kock from January 1, 1981 to August 7, 1989; Stals from August 8, 1989 to August 7, 1999; Mboweni from August 8, 1999 to November 8, 2009 and Marcus from November 9, 2009 to November 8, 2014.

Lakdawala (2016), Belongia and Ireland (2016) and Keating and Valcarcel (2017). Further, most of these studies only examine the effect of monetary policy innovations on the economy, for example Primiceri (2005), Baxa et al. (2014) and Lakdawala (2016). This chapter is different, however, for its main contribution to the literature is that it focuses on the role played by changes in central banks' policy preferences and its associated shock volatility on the economy due to monetary policy conduct. Two algorithms are used to determine whether there are time–varying monetary policy parameters which capture changing policy authorities' model parameters and, thus, regime changes. The algorithms are the Kalman filter and the independence Metropolis-Hastings. The Kalman filter is used to obtain the estimates of the time-varying parameter Taylor type rule. The independence Metropolis-Hastings computes the dynamic responses and stochastic volatility within a setup of a time-varying parameter of a Taylor-type rule. This implies that the variances of the stochastic processes vary over the sample period.

The importance of this undertaking is twofold. First, changes in policy authorities' preferences are characterised by the possibility of time-varying monetary policy regime changes that may be influenced by the changing structure of the economy and different governors at the central bank. Secondly, this chapter adds to the existing research about South Africa, where changes in policy regime investigations are carried out under the assumption of time-invariant policy parameters.[2] Therefore, the relevance of this chapter is that it shows that at different points in time and over different monetary policy regimes, the economy responds differently to policy shocks. Also, a counterfactual analysis is provided to estimate time-varying parameters that capture changing policy preferences. More specif-

[2] This includes sub-sample, instrumental variables and a generalised method of moments (GMM) that are weak to capture the changing dynamics of the economy (see Aron and Muellbauer (2002), Ortiz and Sturzenegger (2007), Gupta et al. (2010) and Naraidoo and Raputsoane (2015)). Further, other literature that evaluates monetary policy conduct focuses on a nonlinear econometric framework and asymmetric preferences that include Naraidoo and Paya (2012) and Baaziz (2015).

ically, alternative issues, such as how monetary policy would have been with no change in governors, no monetary policy regime changes and the impact of the financial crisis in 2008 on the South African economy, is evaluated.

The findings suggest that the SARB changed its policy responses to inflation and output from the beginning of the 1980s. In an inflation targeting regime the dynamic responses to output are higher than the responses in a monetary aggregates regime.[3] Throughout the sample period, variations in the policy parameters are found. Furthermore, the baseline results are robust to the output gap characterisation of monetary policy conduct. That is, volatility of the policy innovations show upward persistence in the output gap but remain low in the policy rate and in inflation which is similar to the baseline results.

This study also found that the SARB's policy parameters for output stability increased significantly between 2000 and 2007, then shifted to inflation stability in 2008.[4] These findings relate to those of Lakdawala (2016) and Belongia and Ireland (2016), who find that the Federal Reserve Board attached larger weight to output than inflation from 2000 to 2007. All the counterfactual experiments carried out herein suggest that regime changes exert substantial effects on central banks' loss function parameters for output and inflation compared to potential outcomes, had there not been a regime change.

The remainder of this chapter is as follows: section two surveys the literature; sections three and four lay out the theoretical model and estimation strategies, while section five presents the empirical results. Section six provides some remarks and a conclusion.

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[3]That is, inflation targeting began February 2000 and is the existing monetary policy framework and a monetary aggregates regime started between 1986 and 1999.

[4]During this period, the South African consumer price index inflation exhibited a rising trajectory over the years 2006 and 2008 and inflation peaks in August 2008 at about a 12 per cent. This is also consistent with oil price peaking over the June and July 2008 period. This could have led to a change in policy parameters towards inflation stability.

3.2 Related Literature

This section surveys the literature to ascertain the effects of changes in monetary policy regimes and the behaviour of central banks. Changing central bank preferences as well as the changing structure of an economy raise significant issues about monetary policy conduct. Thus important issues surround whether central banks behaviour changes over time and whether changes in monetary policy regimes explain low volatility in macroeconomic variables, such as inflation and output.

To address these questions, Taylor (1993) proposes a monetary policy rule that characterises monetary policy conduct and thus exhibits the conduct of the Federal Reserve Board.[5] This means that the Taylor rule contains information on central banks' preferences and policy authorities' views about the structure of the economy.

With regards to the central bank preferences, a puzzle that has emerged about the Taylor rule is: what is the optimal trade-off between inflation and output preference parameters of central banks? In the Taylor rule, a preference parameter of inflation larger than one suggests that changes in the interest rate are strong enough to stabilise inflation. Taylor (1999) shows that when the inflation parameter is smaller than one, a positive inflation shock leads to an increase in a nominal interest rate, which is not sufficient to help reduce the real interest rate and may destabilise the economy. To examine policy authorities' views about the state of the economy, the formal approach is to minimise the central bank loss function together with private agents' optimisation problems. When the weight on output is zero in the loss function, the central bank does not care about the output gap. If, however, the output parameter is not zero, then there is a possibility

[5]The initial policy rule suggests that the nominal interest rate should be set to a long run interest rate plus a weighted average of a real GDP gap and a four-quarter moving average of actual GDP deflator less target inflation. But the Taylor rule did not specify the target inflation of the central bank. The focus was on how central banks should set the policy rule with weights of 1.5 and 0.5 for GDP deflator and GDP gap, respectively.

of a dual objective of inflation and output stability. On the contrary, Woodford (2003a) suggests that incorporating the output gap in the loss function does not imply that central banks have dual objectives. Instead, the output gap may have predictive content about inflation and output stability.

Over the past two decades, the Taylor rule has attracted attention from policy authorities. Though the literature has proven that the Taylor rule fits central banks' preferences well in a number of advanced and emerging economies, no consensus has emerged on the appropriate specification of the Taylor rule for all economies (see Woodford (2015), Taylor (2014) and McCallum (2015)).

Alternative monetary policy rules, however, have been proposed due to some weaknesses of the Taylor rule. This includes a lack of forward-looking in the Taylor rule, parameter instability and data uncertainty that may lead to multiple equilibria. These researchers include Taylor (1999), Sack and Wieland (2000), Svensson (2003) and others. An important point in the discussion of alternative monetary policy rules is whether the policy preference parameters change over time in relation to personalities at the helm of the central bank. Among others, Boivin (2005) and Kim and Nelson (2006) estimate Taylor-type rules and find that the behaviour of the Federal Reserve Board changes over time. Further, the Federal Reserve Board reacted less to real economic activity in the 1980s compared to the 1970s. Similarly, Kuzin (2006) and Assenmacher-Wesche (2006) use a backward-looking Taylor rule with money target as the instrument, and find that the Bundesbank sensitivity to inflation varies over time. They indicate that the Bundesbank places more weight on inflation relative to the Federal Reserve Board.

Furthermore, Taylor (1999) and Ball and Mazumder (2011) posit that monetary policy shifts anchored inflation in the 1980s and 1990s. These studies used historical, split sample and instrumental variable techniques to investigate the effects of monetary policy on inflation and output. Unfortunately, these techniques are unable to capture heterogeneity across the entire sample period as well as nonlinear dynamic patterns, such as amplitude dependence and asymmetries. This chapter, therefore, seeks to address this issue by employing a time-varying coefficients with multivariate stochastic volatility. Because the inflation targeting performance of different monetary policy regimes did not affect developed economies, but inflation targeting emerging economies benefited (Ball; 2010; Mishkin and Schmidt-Hebbel; 2007; Abo-Zaid and Tuzemen; 2012). These studies also ascertain that the conduct of monetary policy by the European Central Bank has less effect on national central banks.

According to Lucas (1976), orthodox macroeconometric techniques are weak in accounting for the link between macroeconomic fundamentals and policy regime shifts. The Lucas critique has revolutionised macroeconometrics, resulting in a new class of estimation strategies. One of the estimation strategies is the reduced-form Markov-switching model of Hamilton (1989). Markov-switching studies show that central banks respond to policy regime shifts and there are improvements in the fit with persistent heterogeneity in the policy rule (see Sims and Zha (2006), Lange (2010) and Canova and Ferroni (2012)). A difficulty with reduced-form Markov-switching analyses is that it may not be easy to interpret the unobservable state variables and is not suitable for nonstationary data.

To overcome these problems associated with the Markov-switching model, this chapter employs a time-varying parameter technique. A time-varying parameter technique allows one to capture the changes across the entire sample period and considers the patterns of models with nonlinear dynamics (see Primiceri (2005), Trecroci and Vassalli (2010), Korobilis (2013), Baxa et al. (2014), Lakdawala (2016) and Belongia and Ireland (2016)). Further, the central message of these authors is that exogenous and endogenous shocks explain high volatility in inflation over the 1970s compared to the 1980s. That is, inflation volatility declined and unexpected changes in monetary policy shocks affected output, exchange rate and money growth. Consequently, traditional techniques of splitting samples may provide misleading empirical results of monetary policy outcomes.

In emerging economies, Mohanty and Klau (2005), Perrelli and Roache (2014) and others estimate monetary policy regime changes, and suggest that central banks allocate more weight to output than inflation and also allocate some weight to the exchange rate. Further, some policy authorities react to financial and banking stress indicators and also to the exchange rate in small open economies, see Batini et al. (2003) and Baxa et al. (2013).

In South Africa, there are quite a number of recent studies (Ortiz and Sturzenegger (2007), Steinbach et al. (2009), Alpanda et al. (2010) and Peters (2016)). However, these authors' analyses are confined to constant parameter estimations. Ortiz and Sturzenegger (2007) use a rolling regression in a dynamic general equilibrium model to examine the SARB policy strategies. They find that the SARB exhibits an anti-inflation bias, has increased its weight on the output gap, and attaches a low weight to the exchange rate.[6]

Some of the findings of a constant parameter analyses in South Africa are summarised in Table 3.1. From Table 3.1, most of the findings of the SARB's policy

Table 3.1: Summary of literature results in South Africa

Author(s)	Sample	Method	Inflation	Output
Aron and Muellbauer (2002)	1986:Q2 -1997:Q4	IV	-0.19 (5.80)	0.37 (3.70)
Mohanty and Klau (2005)	1990:Q1-2002:Q4	GMM	0.04 (7.09)	0.07 (7.53)
Ortiz and Sturzenegger (2007)	1983:Q1 - 2002:Q4	RR	1.11	0.27
Alpanda et al. (2010)	1994:Q1 - 2008:Q4	BM	1.42	0.29
Naraidoo and Raputsoane (2015)	2000:M1 - 2012:M4	GMM	1.43 (29.08)	0.60 (17.06)
Peters (2016)	1979:Q3 - 2007:Q3	ML	0.84 (6.10)	0.07 (1.40)

Source: Author's compilation August 31, 2016. Note: BM is Bayesian method, IV is instrumental variables, GMM is generalised method of moments, ML is maximum likelihood estimates and RR is rolling regression. t-statistics in parentheses.

preferences are not different from advanced and other emerging economies. How-

[6] However, they admitted that the method used is weak to—account for interventions used by the SARB to control inflation, output and the exchange rate.

ever, the question that arises is: does the weight allocated to output and inflation preferences change over time? To answer this question, it is necessary to model monetary policy regime changes in a time-varying setting. This chapter, therefore, analyses the preferences of the SARB while using a time-varying parameter approach that may allow one to understand how monetary policy regime changes have evolved over time.

3.3 The Model

This section presents a baseline open economy model that could be modified to be consistent with a closed economy model. A structural small open economy model of Gali and Monacelli (2005) is used. Rotemberg and Woodford (1997) discuss a similar New Keynesian monetary policy structural model. This model is used to characterise the South African economy. The small open economy model blocks are as follows:[7]

$$\pi_t = \beta_\pi \pi_{t+1|t} + \kappa_\alpha y_t + \mu_{\pi,t}, \tag{3.1}$$

$$\pi_t^{cpi} = \pi_t + \alpha(s_t - s_{t-1}) = \pi_t + \alpha(\Delta s_t), \tag{3.2}$$

$$q_t = q_{t+1|t} - (1-\alpha)(i_t - \pi_{t+1|t}) + (1-\alpha)(i_t^f - \pi_{t+1|t}^f) + (1-\alpha)\mu_{q,t}, \tag{3.3}$$

$$y_t = y_{t+1|t} - \beta_{\rho,t}(i_t - \pi_{t+1}) + \mu_{y,t}. \tag{3.4}$$

Eqn. (3.1) is the aggregate supply function, π_t denotes domestic inflation, β_π is the rate of time preference and y_t is the output gap and $\mu_{\pi,t}$ is the supply shock at time $t-k$ that is not accounted for at time t and has zero mean independently identically distribution (i.i.d.).

Eqn. (3.2) characterises the consumer price index inflation, where s_t is the terms of trade and shows the effect of imported goods on consurmer price inflation. Eqn. (3.3) links the uncovered interest rate parity condition to the real exchange

[7]Where $\kappa_\alpha = \dfrac{(1-\theta)(1-\beta\theta)}{\theta}(\vartheta + \dfrac{\theta}{\omega_\alpha})$, α is the degree of openness which is the share of domestic expenditure on foreign goods. A larger parameter means that the domestic economy is more open and $\beta_p = \dfrac{\omega_\alpha}{\sigma}$.

rate. i_t is the policy rate, i_t^f and π_{t+1}^f are the foreign interest and inflation rates with zero mean i.i.d and $\mu_{q,t}$ is the exchange rate risk premia.

Eqn. (3.4) is the aggregate demand function and all the parameters are nonnegative, where $\rho_t = i_t - \pi_{t+1}$ is the real interest rate and $\mu_{y,t}$ is the demand shock with zero mean i.i.d. q_t is the real exchange rate and is measured as follows

$$q_t \equiv s_t + p_t^h - p_t = (1-\alpha)s_t, \tag{3.5}$$

Eqns. (3.1)- (3.3) of these model blocks collapse to a closed economy model similar to Clarida et al. (2002) and Woodford (2003a), that is, if either $\alpha = 0$ or $\omega_\alpha = \sigma\eta = 1$, then $\kappa_\alpha = \dfrac{(1-\theta)(1-\beta\theta)}{\theta}(\vartheta + \theta)$ and $\beta_\rho = \dfrac{1}{\sigma}$.

The optimising central bank intertemporal loss function in an open economy as an unconditional expectation of the form is written thus

$$E_t \sum_{k=0}^{\infty} \beta^k L_{t+k}, \tag{3.6}$$

as $\beta \to 1$, the central bank single-period loss function takes the form

$$L_{t+k} = \lambda_{\pi^{cpi},t+k}(\pi_{t+k|t}^{cpi})^2 + \lambda_{y,t+k}(y_{t+k|t})^2 + \lambda_i(i_{t+k} - i_{t+k-1})^2. \tag{3.7}$$

The parameters $\lambda_{\pi^{cpi},t+k}$, $\lambda_{y,t+k}$ and $\lambda_{i,k-1}$ are the weights central banks place on inflation, output stability and interest rate smoothing.

The interest rate smoothing term is added to account for the possibility of policy authorities' desire to gradually adjust their policy rates and thus captures inertia in policy rate adjustments, see Clarida et al. (1999) and Woodford (2003a). Similarly, see also Sack and Wieland (2000), who are critical of the interest rate smoothing argument. In this case, the dual mandate of the central bank is consumer price inflation and output stability.

All the weights are nonnegative and also time-varying, except for the weight for the interest rate smoothing. The time-varying concept allows for a departure from the basic central bank loss function, in that the weight attached to inflation relative to output stability varies over time.[8] There are a number of reasons to model the

[8]However, here it is assumed that the weight a central bank attaches to interest rate smoothing does not change over the sample period.

parameters as time-varying. First, these weights change with a particular central bank governor or the composition of the monetary policy committee. For example, a new governor may exhibit an anti-inflation bias, whereas another governor may accommodate inflation. Secondly, the degree of political pressure on monetary policy authorities may change central bank preferences. This changing political pressure can be accounted for by a time variation in the weights the committee attaches to inflation relative to output stability. Thirdly, periods of economic uncertainty—such as the Asian currency crisis in 1998 and the global financial crisis over the period 2007 and 2008—may account for changes in the weights that a central bank attaches to inflation relative to output stability.

To close the present model, a monetary policy rule that follows a Taylor-type rule is derived and used to show how a central bank responds to macroeconomic variables. Eqn. (3.3) is respecified in the form

$$i_t - \pi_{t+1|t} = \frac{1}{(1-\alpha)}[q_{t+1|t} - q_t] + (i_t^f - \pi_{t+1|t}^f) + \mu_{q,t}, \tag{3.8}$$

substituting eqn. (3.8) into eqn. (3.4) yield

$$y_t = y_{t+1|t} - \beta_{p,t}[\frac{1}{(1-\alpha)}(q_{t+1|t} - q_t) + i_t^f - \pi_{t+1|t}^f + \mu_{q,t}] + \mu_{y,t}. \tag{3.9}$$

Further, following Dennis (2007), the foreign interest rate, inflation and exchange rate risk premium are normalised to zero. Then re-arranged to yield

$$y_{t+1|t} = y_t + \beta_{p,t}[\frac{1}{(1-\alpha)}(q_{t+1|t} - q_t)] - \mu_{y,t}. \tag{3.10}$$

From eqn. (3.5), if the extent of openness is non-zero, that is, $\alpha \neq 0$, then $s_t = \dfrac{q_t}{1-\alpha}$ and $s_{t-1} = \dfrac{q_{t-1}}{1-\alpha}$. Therefore, s_t and s_{t-1} are replaced with q_t and q_{t-1}, respectively in eqn. (3.2) to yield.

$$\pi_t^{cpi} = \pi_t + \frac{\alpha}{1-\alpha}(q_t - q_{t-1}) = \pi_t + \frac{\alpha}{1-\alpha}(\Delta q_t). \tag{3.11}$$

Similarly, eqn. (3.11) is iterated one period ahead and conditional expectations are taken at time t to yield the following:

$$\pi_{t+1|t}^{cpi} = \pi_{t+1|t} + \frac{\alpha}{1-\alpha}(q_{t+1|t} - q_t). \tag{3.12}$$

Eqns. (3.12) and (3.10) are substituted into eqn. (3.7) and using $q_{t+1|t}$ as a control variable similar to Ball (1999), and the central bank loss function is solved to yield

$$[q_{t+1|t} - q_t] = -\frac{\lambda_{y,t}\beta_{p,t}}{(1-\alpha_t)[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}y_t - \frac{\lambda_{\pi^{cpi},t}\alpha_t}{(1-\alpha_t)[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\pi_{t+1|t}$$
$$+ \frac{\lambda_{y,t}\beta_{p,t}}{(1-\alpha_t)[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\mu_{y,t}, \tag{3.13}$$

Eqn. (3.8) thus becomes $i_t - \pi_{t+1|t} = \dfrac{1}{(1-\alpha)}[q_{t+1|t} - q_t]$, because $i_t^f = \pi_{t+1|t}^f = \mu_{q,t} = 0$ are normalised to zero and substitute eqn. (3.13) into it to yield

$$i_t = \left(1 - \frac{\lambda_{\pi^{cpi},t}\alpha_t}{(1-\alpha_t)^2[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\right)\pi_{t+1|t}$$
$$- \frac{\lambda_{y,t}\beta_{p,t}}{(1-\alpha_t)^2[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}y_t + \frac{\lambda_{y,t}\beta_{p,t}}{(1-\alpha_t)^2[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\mu_{y,t}. \tag{3.14}$$

The parameters in eqn. (3.14) are summarised to yield

$$i_t = f_{\pi,t}\pi_{t+1|t} + f_{y,t}y_t + \xi_{k,t}. \tag{3.15}$$

where $f_{\pi,t} = \left(1 - \dfrac{\lambda_{\pi^{cpi},t}\alpha_t}{(1-\alpha_t)^2[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\right)$,

$$f_{y,t} = \left(-\frac{\lambda_{y,t}\beta_{p,t}}{(1-\alpha_t)^2[\lambda_{\pi^{cpi},t}\frac{\alpha_t}{1-\alpha_t}^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\right),$$

and $\quad \xi_{k,t} = \left(\dfrac{\lambda_{y,t}\beta_{p,t}}{(1-\alpha_t)^2[\lambda_{\pi^{cpi},t}(\frac{\alpha_t}{1-\alpha_t})^2 + \lambda_{y,t}(\frac{\beta_{p,t}}{1-\alpha_t})^2]}\right)\mu_{y,t}.$

Eqn. (3.15) is the open economy optimal monetary policy rule. This implies that a central bank adjusts its policy rate on the basis of expected domestic price inflation, output gap, and innovations hitting the economy. Thus, changes in policy rate is determined by changes in a structural small open economy model. Clarida et al. (2002) demonstrate that eqn. (3.15) is an optimal monetary policy rule and takes the form of a Taylor-type rule.

For lack of quarterly forecast data on inflation and output over the sample period 1970:Q1 and 2014:Q4, as well as computational convenience, a backward-looking Taylor-type rule is used. According to McCallum (1999), a policy rule with backward features characterise the data well, because informational assumption are more realistic. It is acknowledged that policy authority responds to an expected inflation and output gap by using a wide array of variables, which have predictive content about the expected inflation and output gap. Thus two lags of the policy rate in eqn. (3.15) are taken to account for the interest rate smoothing in line with Woodford (2003b), who argues that an optimal Taylor-type rule takes into account an interest rate of recent past levels with approximate lags of two. In this chapter, however, the primary interest is on the weights central banks put on inflation relative to output stability. It is further assumed that monetary policy shocks on inflation and output are subdued after three and two lags. This is in line with Svensson (1999), who argues that the real policy rate has a longer effect on inflation than does output. This gives a modified optimal Taylor-type rule of the form

$$
\begin{aligned}
i_t = & f_{i1,t} i_{t-1} + f_{i2,t} i_{t-2} + f_{y,t} y_t + f_{y1,t} y_{t-1} + f_{y2,t} y_{t-2} \\
& + f_{\pi,t} \pi_t + f_{\pi 1,t} \pi_{t-1} + f_{\pi 2,t} \pi_{t-2} + \xi_{k,t}.
\end{aligned} \tag{3.16}
$$

3.4 Econometric and Estimation Strategies

3.4.1 Econometric Layout

A time-varying parameter model allows for modeling the possibility of changes in monetary policy preferences that may be influenced by changes in macroeconomic variables, changes in central bank governors and in lower and upper bounds of target variables. Here a time-varying parameter approach is used to estimate the Taylor-type rule in eqn. (3.16). The time-varying monetary policy rule measurement and transition equations are as follows

$$X_t = Z_t \beta_t + \varepsilon_t \quad \varepsilon_t \ is \ i.i.d. \sim N(0, I_t), \tag{3.17}$$

$$\beta_t = \beta_{t-1} + \eta_t \quad \eta_t \ is \ i.i.d. \sim N(0, Q_t). \tag{3.18}$$

Eqn. (3.17) is the measurement equation. Where $X_t = [i_t, \pi_t^{cpi}, y_t]$ are vectors containing system observed variables with $M \times 1$ dimension, $Z_t = I_t \otimes [i_{t-1}, i_{t-2}, y_t, y_{t-1}, y_{t-2}, \pi_t, \pi_{t-1}, \pi_{t-2}]$ is $M \times k$ matrix that defines each time-varying parameter vector autoregressive equation, and contains two lags of each observed variable.

Eqn. (3.18) is the transition equation, where $\beta_t = [f_{i,t}, f_{y,t}, f_{\pi^{cpi},t}]$ are the structural parameters of the model. This is similar to an econometric model used by Primiceri (2005) and Cogley et al. (2010) to account for gradual changes in monetary policy conduct.[9] Thus the estimators β_t attach more weights to current observations than past observations whereas OLS assigns equal weights to all observations. Therefore, a time-varying parameter generates smooth estimates of discrete changes, resulting in parameters starting to gradually change before the actual break date. Thus, it is possible to determine whether the identified changes are consistent with a discrete break model.

$\varepsilon_t = (\xi_{k,t})$ is a vector of structural innovations with zero mean and a time-varying covariance matrix I_t decomposed as $I_t = A_t^{-1} H_t (A_t^{-1})^1$, where H_t is a vector containing the diagonal elements of $h_{kj,t}$ of the form

$$H_t = \begin{pmatrix} h_{11,t} & 0 & 0 \\ 0 & h_{22,t} & 0 \\ 0 & 0 & h_{33,t} \end{pmatrix}. \tag{3.19}$$

A lower triangular matrix A_t is specified to simulate the relation of the structural shocks by recursive identification. A_t assumes a diagonal element equal to one of the form

$$A_t = \begin{pmatrix} 1 & 0 & 0 \\ a_{21,t} & 1 & 0 \\ a_{31,t} & a_{32,t} & 1 \end{pmatrix}, \tag{3.20}$$

[9] If, however, the changes are discrete jumps for all parameters simultaneously, the time-varying parameter estimates will not be reliable. Even though this occurs in special cases, the time-varying parameter can provide a useful approximation when there are discrete jumps.

$a_{kj,t}$ and $h_{kj,t}$ are assumed to follow a random walk similar to Nakajima et al. (2011) of the form

$$a_{kj,t} = a_{kj,t-1} + \zeta_t \qquad \zeta_t \sim N(0, S), \tag{3.21}$$

$$lnh_{kj,t} = lnh_{kj,t-1} + \sigma_k \mu_t \quad \mu_t \sim N(0, W) \;\; and \;\; j \in [y_t, \pi_t, i_t], \tag{3.22}$$

where $a_{kj,t}$ is modeled as a driftless random walk and $h_{kj,t} = [h_{i,t}, h_{y,t}, h_{\pi,t}]$ are vectors of volatilities assumed to evolve as a geometric random walk independent of each other. η_t, ζ_t and μ_t in eqns. (3.18), (3.21) and (3.22) are i.i.d. The variance-covariance W in eqn. (3.22) depends on the free parameter of σ_k. A block-diagonal structure is imposed to make the blocks of E independent to enable the covariance state to be estimated equation by equation. E is of the form

$$E \begin{pmatrix} \varepsilon_t \\ \eta_t \\ \zeta_t \\ \mu_t \end{pmatrix} \equiv var(\xi) = \begin{pmatrix} I_3 & \theta_{3\times21} & \theta_{3\times3}, & \theta_{3\times3} \\ \theta_{21\times3} & Q & \theta_{21\times3} & \theta_{21\times3} \\ \theta_{3\times3} & \theta_{3\times3} & S & \theta_{3\times3} \\ \theta_{3\times3} & \theta_{3\times3} & \theta_{3\times3} & W \end{pmatrix}. \tag{3.23}$$

Once I_t in eqn. (3.17) and Q_t in eqn. (3.18) are specified, prior condition for the initial values $(\beta_0, I_0 \, and \, Q_0)$ and priors for any remaining parameters of the model are specified, then Bayesian inference can follow using Markov Chain Monte Carlo (MCMC).

3.4.2 Choice of Priors

The MCMC method involves numerical sampling from the posterior distribution which is carried out through the Kalman filter and the independence Metropolis-Hastings (MH) algorithms. The Kalman filter is applied to eqns. (3.17) and (3.18) to obtain the estimates of the time-varying parameter Taylor-type rule in eqn. (3.16), see Appendix A 3.7.1 for how the algorithm is initiated. What is new is that the weight attached to each explanatory variable is assumed to vary over time. As the central bank's preferences change, the weight attached to each explanatory variable also changes.

The independence MH algorithm is implemented to obtain the estimated time-varying parameter dynamic responses and stochastic volatility. Here, in line with Jacquier et al. (2002), a brief explanation of the estimation steps is provided and the generic steps are provided in Appendix A 3.7.2. For the training sample, a standard time invariant vector autoregression using OLS is estimated. The first ten years of the observations are used as the training period to obtain the priors. The priors for the time-invariant parameters are assumed to be normal with the prior means equal to the OLS estimates for the training sample. The prior variances are set high enough to make them non-informative.

The prior for Q in eqn. (3.18) captures the variances of the prior preference parameters and is set to the inverse Wishart distribution. The posterior distribution of Q comes from the same distribution of the prior distribution of Q. A large value of Q implies more stochastic volatility in the central bank's preference parameters. For this reason the scale factor of 0.00035 is set in line with Benati and Mumtaz (2007). Using that initial data, the starting values for $h_{kj,t}$ in eqn. (3.22), $t = 0...T$ and $k = 1, 2, 3$ are obtained as the variances W in eqn. (3.22) and the priors for σ_k and $\mu_t = 0.0001$ with μ_t in eqn. (3.22) are set as inverse Gamma distribution. Because the marginal likelihood distributions of μ_t depend on unknown means and variances, if the parameters have an inverse Gamma prior distributions then the conditonal posterior distributions are also inverse Gamma distribution. The initial values for $a_{kj,t}$ in eqn. (3.21) are set equal to the absolute value of $(a_{kj}) \times 10$. In eqn. (3.21), the priors for S_1 is inverse Gamma distribution and S_2 is the inverse Wishart distribution. The initial values of $S_{10} = 0.001$ and $S_{20} = \left(\begin{smallmatrix} 0.001 & 0 \\ 0 & 0.001 \end{smallmatrix}\right)$ are set.

The priors of the policy rate variances ε_t in eqn. (3.17) are assumed to be inverse Gamma distribution. The shape and scale parameter of the inverse Gamma distribution is set to $\alpha = 2$ and $\beta = 1$ to have fairly loose priors. Conditional on A_t, H_t, and Q_t, using the Carter and Kohn algorithm, the variances of ε_t changes at each point in time when the Kalman filter is run.

This simulation exercise is repeated 100,000 times with a burn-in period of 99,000 being discarded. After discarding the samples in the burn-in period, the sample paths look stable, as shown in the left and right panels of Figure 3.14 for the baseline model and robustness check. This implies that the sampling method is efficient with low autocorrelation. All the estimation results below were, therefore, based on 1,000 draws of each parameter that follows.

3.4.3 Data and Descriptive Statistics

South African quarterly data over the period 1970:Q1 to 2014:Q4 and sourced from IMF International Financial Statistics (IFS) are used.[10] The variables used are the real GDP growth rate seasonally adjusted, the consumer price index inflation measured as a percentage change from the corresponding previous quarter, and the SARB policy rate measured as a per cent per annum, which is the repurchase rate (repo rate). The real GDP growth rate is used in the baseline estimates. In the robustness check, the real GDP growth rate is replaced with the output gap, using the Hodrick-Prescott (HP) filter to extract the output gap.

In Table 3.2, when analysing the estimates of the standard deviation and skewness show that the real GDP growth rate is characterised by low volatility relative to the output gap. This evidence supports the use of the real GDP growth rate in the baseline estimates instead of the output gap. The use of the real GDP growth rate is consistent with Orphanides (2001), who argues that ex post revised real GDP values may provide a misleading description of monetary policy conduct.

A cursory look at the descriptive statistics in Table 3.2 and the evolution of the variables plot in the bottom panel of Figure 3.1, suggest that movements in inflation and the repurchase rate are related. The expansion and recovery dynamics of inflation, the real GDP rate and the repurchase rate are consistent with the occurrence of global shocks and how the domestic economy was stabilised by the SARB. Between 1994 and 1998, the repurchase rate rose persistently and

[10] See, http://data.imf.org.

Table 3.2: Descriptive statistics of variables of interest

Variables	Mean	Median	Max.	Min	Std. Dev.	Skewness	Kurtosis	Prob.
Inflation	8.804	9.331	19.250	3.437	5.013	0.042	1.800	0.004
Output gap	0.182	0.214	8.208	-8.266	2.803	0.1335	3.869	0.045
Real GDP	3.210	3.456	9.378	-4.454	2.783	-0.304	2.797	0.214
Repo rate	10.172	9.00	21.250	2.350	4.690	0.403	2.028	0.003

Source: Author's estimation August 31, 2016. Sample size of 180, starting from 1970:Q1 to 2014:Q4.

peaked in 1998, while the real GDP growth exhibits a downward trajectory. This is attributed to the 1994 election leading to capital outflows in the South African economy, and the Asian financial crisis in 1998.

In late 2001, inflation rose significantly and peaked in 2002. It then declined to an all-time low at the end of 2003. This coincided with the 9/11 terrorist attacks and resultant depreciation of the South African rand by approximately 20 per cent in nominal terms. The SARB responded by increasing the repurchase rate cumulatively by 4.00 per cent between December 2001 and September 2002. Inflation trajectories peaked again in 2008. These also coincided with the financial crisis in 2008 and rising oil prices from 2006 that peaked in 2008. Responding to this, the SARB increased the repurchase rate cumulatively by 5.00 per cent between May 2006 and June 2008. With this trend, real GDP growth rates were not spared following similar trajectories over the sample period.

To sum up, all these factors may result in the possibility of changes in the SARB's policy preferences for inflation relative to output.

3.5 Empirical Results

In this section the results from the Kalman filter and Metropolis-Hastings estimates are reported. Tables 3.3 to 3.5 report the mean parameters of changes in

SARB loss function parameters, governors' policy parameters, and counterfactual model parameters. Table 3.6 of Appendix A 3.7.3 provides detail baseline estimates of SARB loss function parameters for the full sample use to simulate the path of the counterfactual estimates. The figures are reported in Appendix A 3.7.3. Figure 3.1 shows the time-varying parameter monetary policy regime changes and Figure 3.2 and 3.3 report governors' policy parameters and the central bank policy parameters of the two regimes. The estimated policy regimes innovations, time-varying dynamic responses and stochastic volatility of the structural innovations are shown in Figures 3.4 and 3.5. Figures 3.6 and 3.7 show the robustness check, whereas the counterfactual simulations are reported in Figures 3.8 to 3.13.

3.5.1 Baseline Results

3.5.1.1 SARB Policy Preferences

In Table 3.3, the magnitudes of inflation and real GDP growth rate parameters are 1.003 and 0.74, respectively over the full sample period. The inflation parameter is consistent with theory because it is greater than or equal to one ($\beta_{inf,t} \geq 1$). This implies that the SARB is active in fighting inflation, for the weight allocated to real GDP growth rate parameter is much greater than 0.50 as proposed by Taylor (1993). This shows that the SARB is also concerned with stabilising output.

Table 3.3: SARB policy preferences

	Inflation	Output
Full Sample		
Real GDP growth	1.0029	0.744
Output gap	1.3932	-0.3051
Policy Regimes		
Monetary aggregates regime	1.1157	0.3831
Inflation targeting regime	0.8574	1.1819

Source: Author's estimation August 31, 2016

The preferences of the SARB over inflation relative to the real GDP growth rate varies, as reported in Table 3.3 and the bottom panel of Figure 3.1. That is, the path of inflation parameter ($\beta_{inf,t}$) and the real GDP growth rate parameter ($\beta_{gdp,t}$) experience significant structural changes. From 1980 to 1998, the SARB followed Taylor's prescription of monetary policy conduct with minimal deviations. The weights attached to inflation and output are 1.12 and 0.38 over the period. When policy regime changes to inflation targeting, the model parameters of inflation and output are reversed to 0.86 and 1.18, respectively. Since the inflation parameter is less than unity, this shows that inflation stability cannot be achieved. The reason for this is that policy fails to prevent the self-confirmed effects of inflation (see Clarida et al. (1999)).

Further, this can be attributed to the fact that in an unofficial inflation targeting period, inflation rate was brought down to about 15 percent average in late 1980s and early 1990s. It further declined below the double digit in December 1992 and moved to an average rate of 5.2 percent in 1999. This trend is very similar to Mariscal et al. (2011), who find that once inflation targeting regime was announced in the UK, economic agents were hopeful that policy authority would deliver on its inflation target. When the Bank of England however, failed to deliver its target within the short term period, economic agents discredited the Bank's ability to deliver on the announced inflation target.

When the two figures in Figure 3.1 are compared, it is found that the trajectory of the inflation parameter is similar to future inflation values (π_{t+1}), but its parameter changes in line with the repurchase rate. Thus, when the repurchase rate is high, the inflation parameter is also high. In the 1990s, inflation parameters and inflation values moved in the opposite direction most of the time, especially from 1990 to 2000. There were, however, small changes recorded around 2000 to 2005. In 1998, the inflation parameter reached its peak at 3.96 during the second quarter, when the repurchase rate was also at its peak. This was as a result of exchange rate shocks triggered by the Asian financial crisis over the period 1997 to 1998.

It can, therefore, be inferred that regime changes have a role to play on the weights the SARB attaches to inflation and output parameters. The switches in policy objectives point to the fact that, in future, policy parameters may change from flexible targeting as witnessed during the 2008 financial crisis in advanced economies. Similarly, this evidence supports the propositon that output growth and low inflation volatility is due to better monetary theories, minimal shocks in the economic environment, and the rule-based monetary policy practice adopted by the SARB.

3.5.1.2 Governors' Tenures

The top panel of Figure 3.1 shows that the weight on inflation rises around the appointment of De Kock. The weight continues to rise to 1.76 in the fourth quarter of 1984 before declining towards the end of the De Kock tenure, as reported in Table 3.6 of Appendix A 3.7.3. Though this coincides with political upheavals and poor sovereign risk rating in the 1980s, the economy was facing large gold price shocks as well as trade and financial sanctions. When Stals stepped in, the weight on the inflation parameter rose persistently and continued in the early years of Mboweni, averaging at 1.59. This is attributed to Stals's main objective of controlling inflation and the effects of large capital outflows prior to the 1994 elections.

During Mboweni's term, the weight on inflation declined until the first quarter of 2006. The weight on inflation began to rise from 0.02 to 0.59 in the first quarter of 2008, as shown in Table 3.6 of Appendix A 3.7.3. Further, the Mboweni era shows that the SARB was more concerned with output growth than inflation stability. This could be attributed to the fact that between 1989 and 1999 under Stals's tenure, the economy recorded an average growth rate of 1.31 per cent compared to 1.80 per cent average growth rate under De Kock that might have put pressure on Mboweni to stimulate the economy, as reported in Table 2.2 in chapter two.

After Mboweni's tenure, Governor Marcus assumed office and the weight on inflation rose relative to output stability. The SARB switched its weights by allocating larger weights to inflation ranging between 0.66 and 1.23 over the period of 2009 to 2014 compared to output, which ranged between 0.16 and 0.62 over the same period as reported in Table 3.6 of Appendix A 3.7.3. Around this period, global uncertainty increased and this may account for a reversal in the SARB's preference for inflation to output. This implies that as economic uncertainty increases, policy authority pays particular attention to inflation stability relative to output growth.

Figure 3.2 supports this interesting evidence that when inflation rises, the weight attached to inflation also rises. What seems most surprising is during Stals's tenure, when inflation was declining, the weight attached to the inflation parameter was relatively high. The repurchase rate is, however, consistent with the weight on the inflation parameter. That is, when the repurchase rate reached its peak, the weight on inflation also reached its peak. This evidence is supported in Table 3.4, where Stals attached 1.59 and 0.38 to inflation and output respectively over the period 1989 to 1999 compared to Mboweni, who allocated 0.62 and 1.62 for inflation and output over the period 1999 to 2009.

Table 3.4: Governors' tenures

	Inflation	Output
Real GDP growth—baseline	1.0029	0.744
De Kock (1981-1989)	0.9198	0.4579
Stals (1989-1999)	1.5864	0.3813
Mboweni (1999-2009)	0.6183	1.6248
Marcus (2009-2014)	0.9146	0.4037

Source: Author's estimation August 31, 2016

It is also important to note that in an inflation targeting regime, Mboweni and

Marcus's preferences for inflation and output are different, as reported in Table 3.4. This suggests that the prevailing economic conditions have larger effects on the design of monetary policy. This clearly has little evidence to support the debate that, because policy authorities around the globe adopted sound monetary policy, that led to stable inflation and output growth over an inflation targeting regime.

To further understand the role played by the estimated model parameters, the policy dynamic responses to inflation and output were compared under the tenure of Mboweni and Stals. In Figure 3.4, a one-time discrete shift with the appointment of Stals and Mboweni was used. This implies that the SARB preferences under the Stals and Mboweni term are the same. The plot shows that a one unit policy shock on inflation in Stals's tenure was approximately 0.45 compared to 0.25 under Mboweni's term. The responses to output under the Mboweni term is approximately 0.60, while under Stals it was about 0.50. The striking feature is that over an inflation targeting regime, more weight was placed on output relative to inflation.

In general, it can be deduced that an inflation targeting regime encourages output growth more so than other policy regimes that have been pursued in previous years.

3.5.1.3 Policy Regimes and Dynamic Responses

The left panel of Figure 3.5 plots the estimated time-varying dynamic responses and stochastic volatility of the structural innovations. This could be described as a time-varying uncertainty. According to the estimated volatility in the left panel of Figure 3.5, uncertainty was high in the early-to-mid 1980s. During the transition from a monetary aggregates target to an inflation targeting regime, volatility increases in inflation and policy rate. Afterwards volatility declines considerably over the inflation target regime. When the monetary policy regime changed from a monetary aggregates regime to an inflation targeting regime in 2000, uncertainty surrounding the real GDP growth rate and the repurchase rate declined. This uncertainty surrounding the inflation rate declined after 12 quarters in 2003. Table 3.6 reinforces this conclusion, when uncertainty declines in relation to the magnitudes of inflation and output parameters in eqn. (3.16), the SARB targets the variable that is less prone to uncertainty. Finally, it is also found that, based on the stochastic volatility of the structural innovations, an effective monetary policy regime depends on the prevailing economic uncertainty and conditions.

The results from the time-varying dynamic responses in the right panel of Figure 3.5, suggest that monetary policy conduct evolves in the early 1980s. Monetary policy shocks to output and inflation vary over the entire sample period. These estimates tell an interesting story. For example in 2000, the policy responses to output was high at negative 2, it fell substantially in 2008 and by 2010 the responses were low at negative 4. Policy shocks to inflation were high in 1995 and there was a significant decline after 2000 through to 2008 and afterwards an increase in inflation responses. The volatility of the policy rate to structural shocks reveals two observations. First, it was stable through the 1990s then it rose at the end of 1998. Secondly, after 1999, there was a sharp decline in volatility of the policy rate. This is expected, in that policy mistakes of setting the policy rate may have been reduced. As pointed out by Cogley et al. (2010), policy authorities in the conduct of monetary policy learn over time how to set the policy rate.

Furthermore, Figure 3.3 reveals an interesting pattern of policy responses to real GDP and inflation over time. An inflation targeting regime is different, as the responses to real GDP growth rate are higher than a monetary aggregates targeting regime. In an inflation targeting regime, the SARB cares more about real GDP growth than inflation stability. But after the financial crisis in 2008, the responses of monetary policy to output were smaller, compared to inflation responses.[11]

[11] The results are similar to Lakdawala (2016) and Belongia and Ireland (2016). For example, in the abstract of Baxa et al. (2014) Contrary to common wisdom, the response becomes less aggressive after the adoption of inflation targeting suggesting the positive effect of this regime on

3.5.1.4 Consistency of Baseline Results with Other Policy Regimes

The results for the changes in the SARB loss function parameters are very similar to those of Lakdawala (2016) and Belongia and Ireland (2016), findings which relate to the Federal Reserve Board (Fed). According to them, the Fed placed more weight on output stability relative to inflation stability from 2000 to 2007. It is found that the behaviour of the SARB monetary policy strategy was similar during the same period. The emphasis on output stabilisation increased significantly after inflation targeting from 2000 until 2005, then the trend reversed during the financial crisis of 2008.

Secondly, the governors' tenures are also consistent with an outcome that different governors may exhibit different monetary policy conduct. Mboweni's policy objectives might be different to those of De Kock and Stals'. The reason is that each governor faces different economic circumstances during their time in office that might shape their beliefs about monetary policy conduct. When Mboweni stepped in, though inflation was accelerating, output growth became a key concern for policy authorities. Therefore, output stability became an important objective to policy authorities as uncertainty associated with the state of the economy increased. This finding is also in line with Lakdawala (2016), who finds that there was a large rise in the weight on inflation with the Federal Reserve Board Chairman Volcker's term, similar to that of Stals's tenure.

The volatility of the structural innovations and dynamic responses of inflation and output are very similar to that of Primiceri (2005), Boivin (2005) and Kim and Nelson (2006) who found that from the middle part of their sample to the end period, inflation volatility was low. As Boivin (2005) suggest, monetary policy conduct changed significantly over the last three decades, but the effect of policy shocks to real activity were weak. This study confirms that the SARB policy changed over the sample period of 1980 to 2014. Further, Primiceri (2005) finds

anchoring inflation expectations. This result is supported by our finding that inflation persistence as well as policy neutral rate typically decreased after the adoption of inflation targeting.

that different variances of policy shocks are important in examining comovements between inflation and output similar to this study findings. The fact that similar findings are obtained from different empirical settings, as well as, different countries is encouraging.

Another interesting piece of evidence is that this result is consistent with other studies in South Africa, as shown in Table 3.1. These studies suggest that the SARB allocates a positive weight to real economic activity during an inflation target regime. Ortiz and Sturzenegger (2007) and Naraidoo and Raputsoane (2015) obtain estimated parameters of 1.11 and 1.43 for inflation while output parameters are 0.27 and 0.60 over their sample period. Conversely, in this study 1.003 and 0.74 for inflation and output are obtained, respectively. Similarly, Alpanda et al. (2010) find that the SARB's preferences for inflation and output were 1.42 and 0.29 in their estimated optimal Taylor rule, and Peters (2016) finds that the SARB attaches significant weight to inflation. This is similar to what is found when the sample is split into monetary aggregates targeting and inflation targeting regimes, as shown in Table 3.3 and Figure 3.3. However, the time-varying parameter with stochastic volatility estimates reveal an important feature that is not found in these works cited above. The responses to inflation and output are both larger, and are important to characterise monetary policy regime changes. Again, this study unravels the behaviour of changes in the SARB's preferences in more interesting ways than that which traditional estimates are unable to discover.

Overall, the characterisation of the changes in central bank policy preferences is consistent with existing findings on issues of timing of the changes and changes in the central banks loss function parameters.

3.5.2 Robustness Check

To gain further insight as to how monetary policy regime changes are carried out by the SARB and to check whether the baseline results are robust, two approaches are used. First, the output gap is used as an alternative measure of real economic activity to output growth. Secondly, the variances of policy shocks are split into three regimes to be in line with OLS estimates.

3.5.2.1 An Alternative Real Economic Activity—Output Gap

The top panel of Figure 3.6 is considerably different from the top panel of Figure 3.1. Thus, the output gap describes the SARB as an anti-inflation policy authority with negative weight allocated to output growth. However, the remaining estimates provide evidence that changes in SARB's loss function parameters were much more substantial. In the left panel of Figure 3.7, the volatility in the policy innovations is much larger with respect to the output gap.

The main difference is that the volatility in the output gap is more pronounced and shows upward movement. The volatility in inflation rates decline consistently over the sample period, but after 2010 inflation volatility begins to rise. The results of volatility in policy rate is consistent with the left panel of Figure 3.5. Similarly, the responses to the output gap, inflation and repurchase rate in the right panel of Figure 3.5 show identical trends with the right panel of Figure 3.7.

3.5.2.2 Policy Regime Variances

In Figure 3.4, three regimes in the variances of the policy innovations are allowed for to detect whether the variances differ in policy innovations. The top panel is the first regime, starting from 1980:Q1 to 1989:Q2. The middle panel is the second regime starting from 1989:Q3 to 1999:Q3, and the bottom panel is the third regime from 2000:Q1 to present. The central message is that the variances of policy innovations are the same, but in 2000 the interval bounds are wide with respect to output compared to the 1980s and after 1989. In addition, the policy rate variance to inflation over the period 1980s is approximately negative 0.50 compared to negative 0.45 and 0.25 over 1989 and 2000, respectively. But the policy rate variance to policy rate remains at approximately 1.50 throughout the three regimes.

The conclusion is that the characterisation of monetary policy regime changes that emanate from the baseline results is robust to policy regime variances and output gap.

3.5.3 Counterfactual Simulations

In this section, an ex post simulation is undertaken to understand, first, what would have happened had Governor Stals's tenure continued? Secondly, it is supposed there was no policy regime change from a monetary aggregates regime to an inflation targeting regime in South Africa. Lastly, it is assumed that the policy authorities in South Africa had not responded to the impact of the financial crisis.

In answering the first question, inflation and output are simulated based on average value of the policy preferences over the tenure of Governor Stals. This is used to transform the observed inflation and output variables. Secondly, policy shocks are held to be constant, with the view that Stals has an anti-inflation bias. Figure 3.8 exhibits the simulated path of inflation and output and Table 3.5 shows the weights allocated to each counterfactual estimate.

Table 3.5: Counterfactual policy preferences

	Inflation	Output
Baseline—full sample		
Real GDP growth	1.0029	0.744
Mboweni's term (1999-2009)	0.6183	1.6248
Counterfactual preferences		
Stals staying on	0.7976	0.7260
No policy regime change	0.8971	0.7875
Financial crisis	0.9458	0.6630

Source: Author's estimation August 31, 2016

The findings suggest that the simulated path of inflation would have been higher along with an increase in output growth, as reported in the bottom panel of Figure 3.8. The SARB would have attached higher weight to inflation, should Governor Stals have stayed on, relative to Governor Mboweni. However, the SARB would have preference for a lower weight on output, which is different to the baseline results as reported in Table 3.5. The volatility of the structural innovations reported in the top panel of Figure 3.9 suggests that the dynamic responses to inflation and output would have been lower, similar to the baseline results. However, the simulated stochastic volatility pattern in the bottom panel of Figure 3.9 do not exhibit similar trends. It can, therefore, be inferred that the structural innovations played a key role in the inflation targeting regime.

The second counterfactual simulation of no policy regime change is performed under the scenerio of holding the year 2000 sample constant. The notion that explicit inflation targeting regime communication takes four quarters to adjust economic agents' belief is acknowledged. Mean values of the weights over the monetary aggregates regime are used to adjust inflation and output variables. The monetary policy rate is adjusted by 100 basis points, similar to Gupta et al. (2010).

The simulation suggests that the weights on policy preferences and the dynamic responses would have been similar to the baseline empirical results with minimal deviations, as shown in Table 3.5 and Figure 3.10. On the contrary, the second panel of Figure 3.11 shows that the counterfactual volatility innovations vary substantially from the baseline findings. This confirms the proposal that the size of the structural innovations contribute to the design of monetary policy over the inflation targeting regime.

Lastly, a counterfactual analysis is conducted to assess the impact of the financial crisis in 2008. In doing this, the policy shocks impacting on the economy and the mean values of the model parameters from 2000:Q1 to 2007:Q3 are fixed to benchmark the credit crisis in August 2007. Figure 3.12 suggests that the crisis would have had an adverse impact on a simulated path of output relative to inflation, had the SARB not responded. Similarly, the dynamic responses to output exhibit a drastic fall and an aggressive anti-inflation bias, as shown in the first panel of Figure 3.13. In the second panel of Figure 3.13, the structural innovations to inflation suggest persistence compared to the baseline results. This suggests that the financial crisis in 2008 would have had greater impact on inflation and output had the SARB not responded to the crisis.

3.6 Conclusion

This chapter proposes that central bank preferences to target inflation and output vary over time. Moverover, different policy preferences by policy authorities may coincide with the term of a particular central bank governor. To examine these changes in central banks' preferences across time, a time-varying parameter approach was used, with the aim of revealing if and how the policy preferences have changed without splitting the sample. This study reveals that the data and the econometric technique support this proposal. The findings in this chapter support the fact that the SARB's loss function parameters change slowly and also coincide with most significant economic events. Such events include shifts in monetary policy regimes, different tenures of SARB governors, social unrest and periods in which the SARB is successfull in reducing inflation along with increase output growth.

It is found that monetary policy conduct is dynamic because weights attached to inflation and output are regime dependent. Further, under the tenure of different SARB governors, the weights allocated to inflation and output differ. Results also suggest that the size of the structural innovations volatility account for a larger part of policy responses to inflation and output. This evidence supports the argument that low volatility in inflation and output is as a result of minimal disturbances over the inflation targeting regime. Although based on different empirical approaches and also in different countries, the findings of the present analysis are comparable with existing research on policy regimes. In particular, changes in policy authority preferences is consistent with issues relating to timing of policy changes and changes in the weights the policy authority allocates to output and inflation.

Finally, it is important to note that a backward-looking time-varying policy regime is used. It would be interesting to use a forward-looking model with and without the interest rate smoothing to understand the monetary policy regime changes in a forward-looking environment. Secondly, it is important to establish the role played by changes in central bank policy parameters on economic performance. This is examined in chapter four, to determine the role played by changing in central bank preferences on the evolution of macroeconomic outcomes.

3.7 Appendix A: Chapter 3

3.7.1 Kalman Filter Algorithm

To estimate a time-varying parameter vector autoregression (TVP-VAR), the Bayesian statistical inference for β_t exploits the Kalman filtering in the following steps

$$\beta_{t-1}|y^{t-1} \sim N(\beta_{t-1}, V_{t-1|t-1}), \tag{3.24}$$

where $\beta_{t-1|t-1}$, and $V_{t-1|t-1,}$ are Kalman filtering proceeds using

$$\beta_{t-1}y^{t-1} \sim N(\beta_{t|t-1}, V_{t|t-1}), \tag{3.25}$$

where $V_{t|t-1} = V_{t-1|t-1} + Q_t$, Q_t enters the Kalman filtering formulae only at this stage, then eqn. (3.25) is respecified as

$$V_{t|t-1} = \frac{1}{\lambda} V_{t-1|t-1}. \tag{3.26}$$

Then Q_t will be estimated or simulated and λ is a factor $0 < \lambda \leq 1$. Eqn. (3.26) is observation j periods in the past with a weight of λ^j in the filtered estimate of β_t. Eqns. (3.25) and (3.26) means that if $\lambda = 1$ then there is a constant coefficient, implying that $Q_t = (\lambda^{-1} - 1)V_{t-1|t-1}$. To avoid constant coefficients, λ is set less than one—for quarterly data $\lambda = 0.99$. This results in a fairly stable model with a gradual change in coefficients that has features similar to those of Cogley and Sargent (2005).

3.7.2 Independence Metropolis-Hastings Algorithm

For the selection of the densities within a setup of a time-varying parameter VAR, the generic candidate density is specified below

$$q(\Phi^{G+1}/\Phi^G) = q(\Phi^{G+1}). \tag{3.27}$$

The full details can be found in Jacquier et al (2002). In general, the acceptance probability formula does not simpify and is given as

$$\alpha = min(\frac{\pi(\Phi^{G+1}/q(\Phi^{G+1}/\Phi^G))}{\pi(\Phi^G)/q(\Phi^G/\Phi^G+1)}, 1) \tag{3.28}$$

unlike the random walk MH algorithm, the independence MH algorithm candidate density generating is tailored to a particular problem at hand. The steps include:
One: setting starting values of the model parameters
Two: drawing a candidate values of the parameters Φ^{G+1} from the candidate density generating
Three: computing the acceptance probability

$$\alpha = min(\frac{\pi(\Phi^{G+1}/q(\Phi^{G+1}/\Phi^{G}))}{\pi(\Phi^{G})/q(\Phi^{G}/\Phi^{G}+1)}, 1) \tag{3.29}$$

Four: if $\mu \sim U(0,1)$ is less than α retain Φ^{G+1}, otherwise retain the old draw.
Five: repeat the step 2-4 M times and base on inference on last likelihood draws.

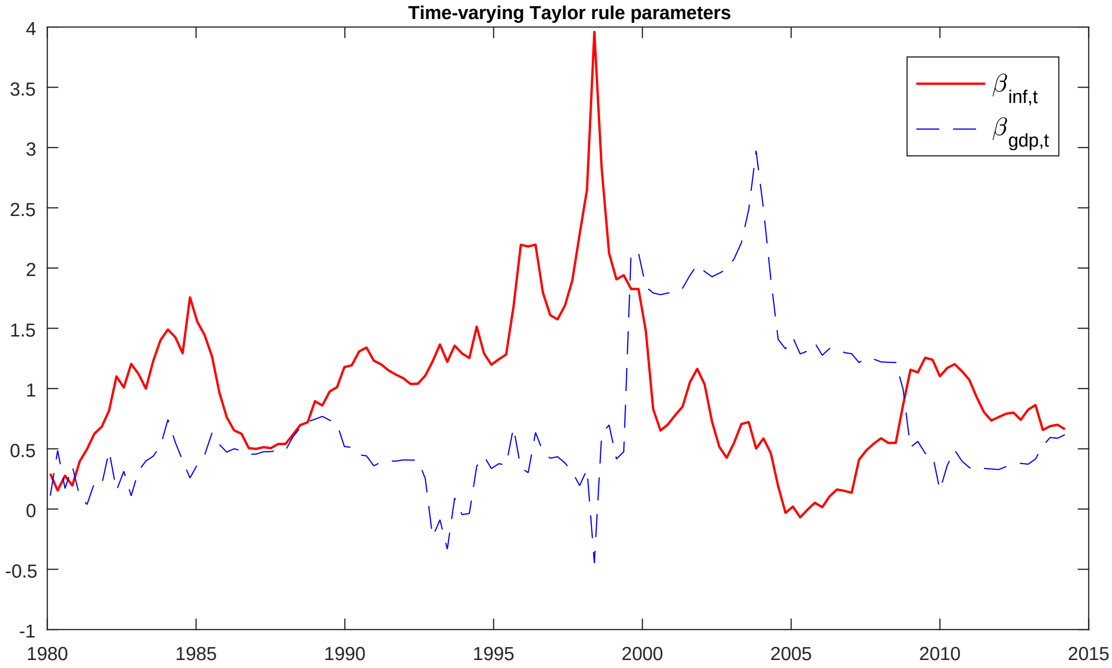
3.7.3 Estimated Results

Table 3.6: Detail baseline policy preference parameters—full sample

Period	Inf.	Out.	Period	Inf.	Out.	Period	Inf.	Out.	Period	Inf.	Out.
1980:Q1	0.294	0.111	1988:Q4	0.720	0.725	1997:Q2	1.689	0.383	2006:Q1	0.015	1.276
1980:Q2	0.154	0.486	1989:Q1	0.895	0.746	1997:Q3	1.897	0.309	2006:Q2	0.106	1.333
1980:Q3	0.277	0.170	1989:Q2	0.860	0.769	1997:Q4	2.281	0.195	2006:Q3	0.162	1.333
1980:Q4	0.196	0.356	1989:Q3	0.975	0.738	1998:Q1	2.651	0.330	2006:Q4	0.151	1.299
1981:Q1	0.396	0.102	1989:Q4	1.012	0.707	1998:Q2	3.960	-0.447	2007:Q1	0.135	1.289
1981:Q2	0.498	0.039	1990:Q1	1.178	0.519	1998:Q3	2.824	0.622	2007:Q2	0.410	1.215
1981:Q3	0.626	0.217	1990:Q2	1.193	0.512	1998:Q4	2.125	0.698	2007:Q3	0.487	1.255
1981:Q4	0.683	0.204	1990:Q3	1.308	0.450	1999:Q1	1.906	0.416	2007:Q4	0.542	1.244
1982:Q1	0.818	0.482	1990:Q4	1.341	0.442	1999:Q2	1.941	0.476	2008:Q1	0.587	1.221
1982:Q2	1.101	0.153	1991:Q1	1.232	0.359	1999:Q3	1.826	2.130	2008:Q2	0.548	1.217
1982:Q3	1.009	0.314	1991:Q2	1.201	0.390	1999:Q4	1.827	2.126	2008:Q3	0.550	1.217
1982:Q4	1.205	0.110	1991:Q3	1.151	0.399	2000:Q1	1.479	1.845	2008:Q4	0.866	0.992
1983:Q1	1.122	0.317	1991:Q4	1.116	0.398	2000:Q2	0.830	1.793	2009: Q1	1.156	0.512
1983:Q2	0.999	0.399	1992:Q1	1.087	0.408	2000:Q3	0.651	1.779	2009: Q2	1.134	0.562
1983:Q3	1.229	0.439	1992:Q2	1.038	0.407	2000:Q4	0.702	1.793	2009: Q3	1.256	0.462
1983:Q4	1.403	0.526	1992:Q3	1.040	0.405	2001:Q1	0.779	1.797	2009: Q4	1.239	0.451
1984:Q1	1.490	0.742	1992:Q4	1.107	0.255	2001:Q2	0.850	1.833	2010: Q1	1.102	0.156
1984:Q2	1.427	0.554	1992:Q4*	1.226	-0.231	2001:Q3	1.053	1.939	2010: Q2	1.171	0.362
1984:Q3	1.293	0.403	1993:Q1	1.366	-0.089	2001:Q4	1.164	2.028	2010: Q3	1.203	0.491
1984:Q4	1.757	0.258	1993:Q2	1.222	-0.333	2002:Q1	1.034	1.972	2010: Q4	1.144	0.398
1985:Q1	1.554	0.369	1993:Q3	1.356	0.091	2002:Q2	0.728	1.928	2011: Q1	1.073	0.345
1985:Q2	1.443	0.450	1993:Q4	1.292	-0.046	2002:Q3	0.516	1.958	2011: Q2	0.929	0.325
1985:Q3	1.266	0.632	1994:Q1	1.253	-0.037	2002:Q4	0.426	1.992	2011: Q3	0.804	0.337
1985:Q4	0.966	0.535	1994:Q2	1.514	0.355	2003:Q1	0.549	2.075	2011: Q4	0.735	0.333
1986:Q1	0.762	0.473	1994:Q3	1.290	0.437	2003:Q2	0.706	2.211	2012: Q1	0.764	0.328
1986:Q2	0.653	0.500	1994:Q4	1.198	0.336	2003:Q3	0.722	2.486	2012: Q2	0.791	0.353
1986:Q3	0.625	0.484	1995:Q1	1.243	0.376	2003:Q4	0.503	2.973	2012: Q3	0.801	0.361
1986:Q4	0.506	0.454	1995:Q2	1.283	0.365	2004:Q1	0.586	2.493	2012: Q4	0.741	0.379
1987:Q1	0.499	0.456	1995:Q3	1.677	0.677	2004:Q2	0.465	1.912	2013: Q1	0.825	0.372
1987:Q2	0.514	0.476	1995:Q4	2.193	0.342	2004:Q3	0.190	1.409	2013: Q2	0.864	0.416
1987:Q3	0.506	0.477	1996:Q1	2.180	0.302	2004:Q4	-0.032	1.329	2013: Q3	0.656	0.525
1987:Q4	0.540	0.487	1996:Q2	2.194	0.635	2005:Q1	0.021	1.423	2013: Q4	0.688	0.594
1988:Q1	0.541	0.488	1996:Q3	1.797	0.478	2005:Q2	-0.069	1.287	2014: Q1	0.700	0.588
1988:Q2	0.618	0.598	1996:Q4	1.609	0.422	2005:Q3	-0.005	1.312	2014: Q2	0.663	0.617
1988:Q3	0.697	0.676	1997:Q1	1.575	0.434	2005:Q4	0.053	1.378	2014: Q3	0.696	0.581

Source: Author's estimation August 31, 2016. Note: Inf=inflation and Out=output

Figure 3.1: Kalman filter estimates of time-varying policy preferences



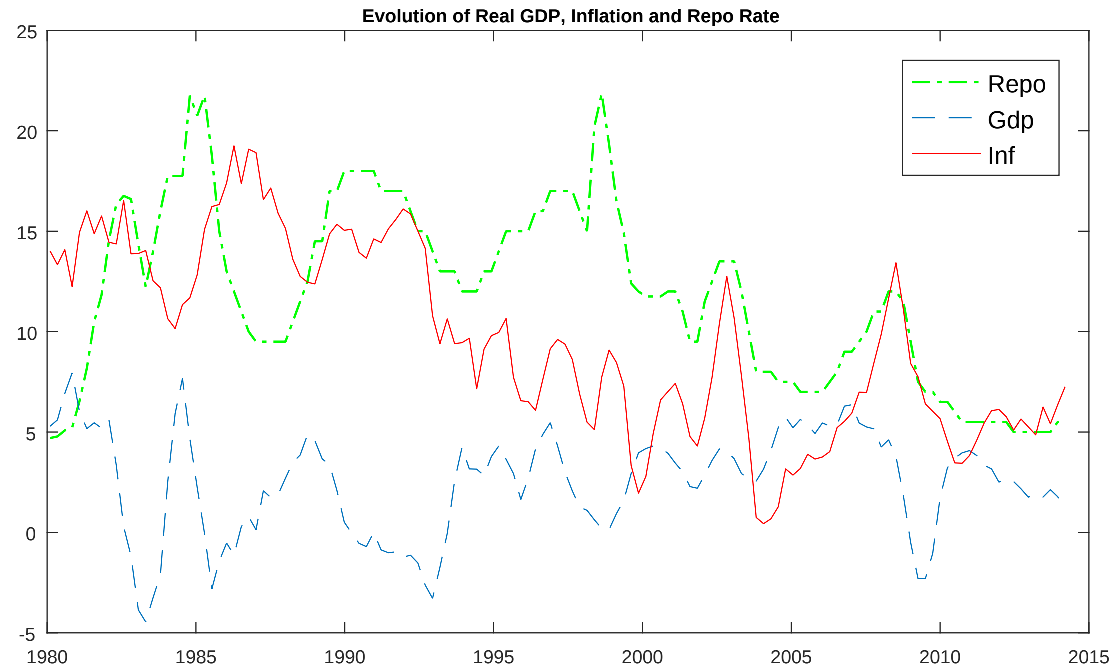


Figure 3.2: Governors' preferences

Note: Top left panel De Kock, top right panel Stals, bottom left panel Mboweni and bottom right panel Marcus

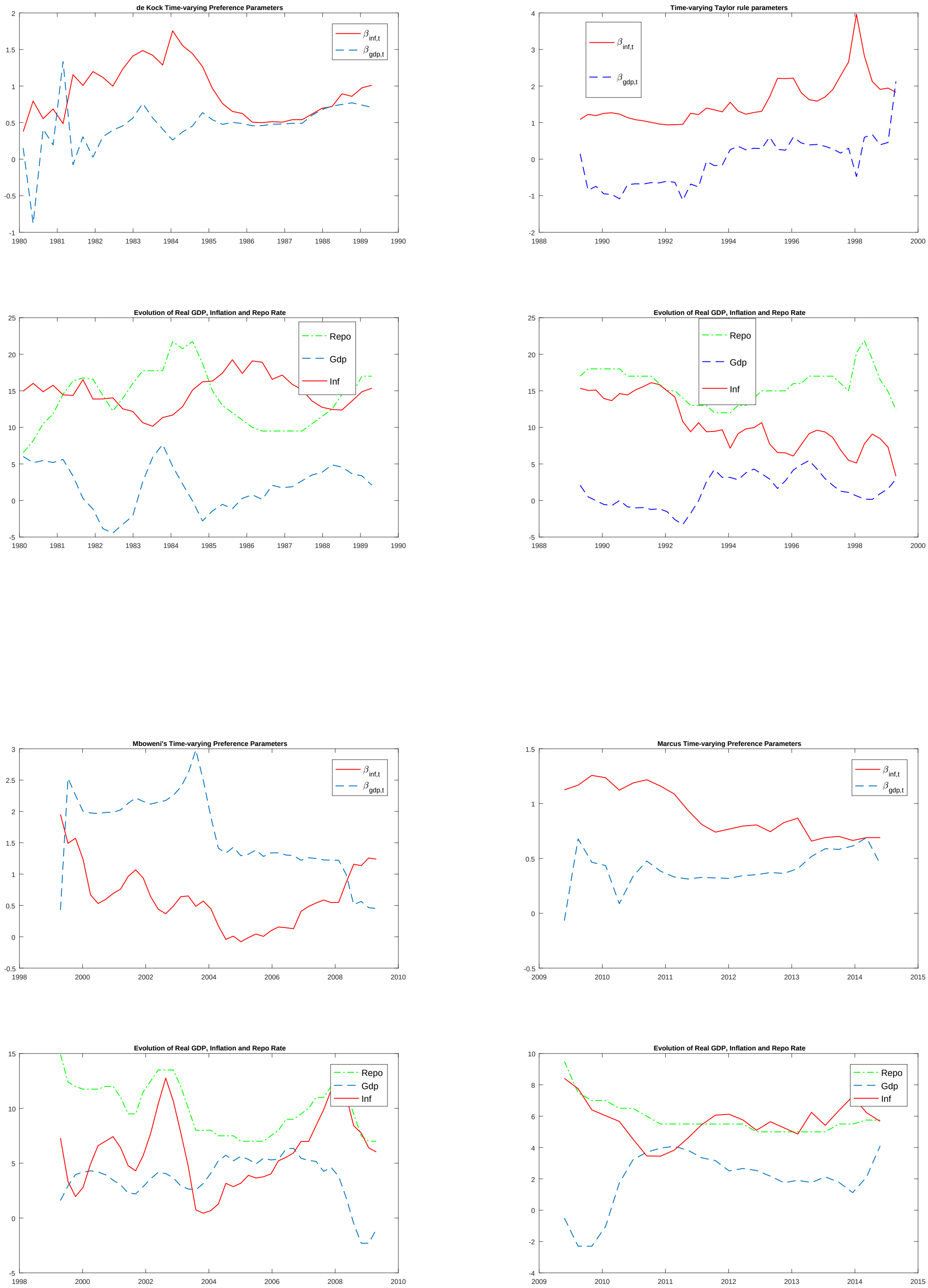


Figure 3.3: Policy regime changes preferences

Note: Left panel monetary aggregates targeting and right panel post-inflation targeting

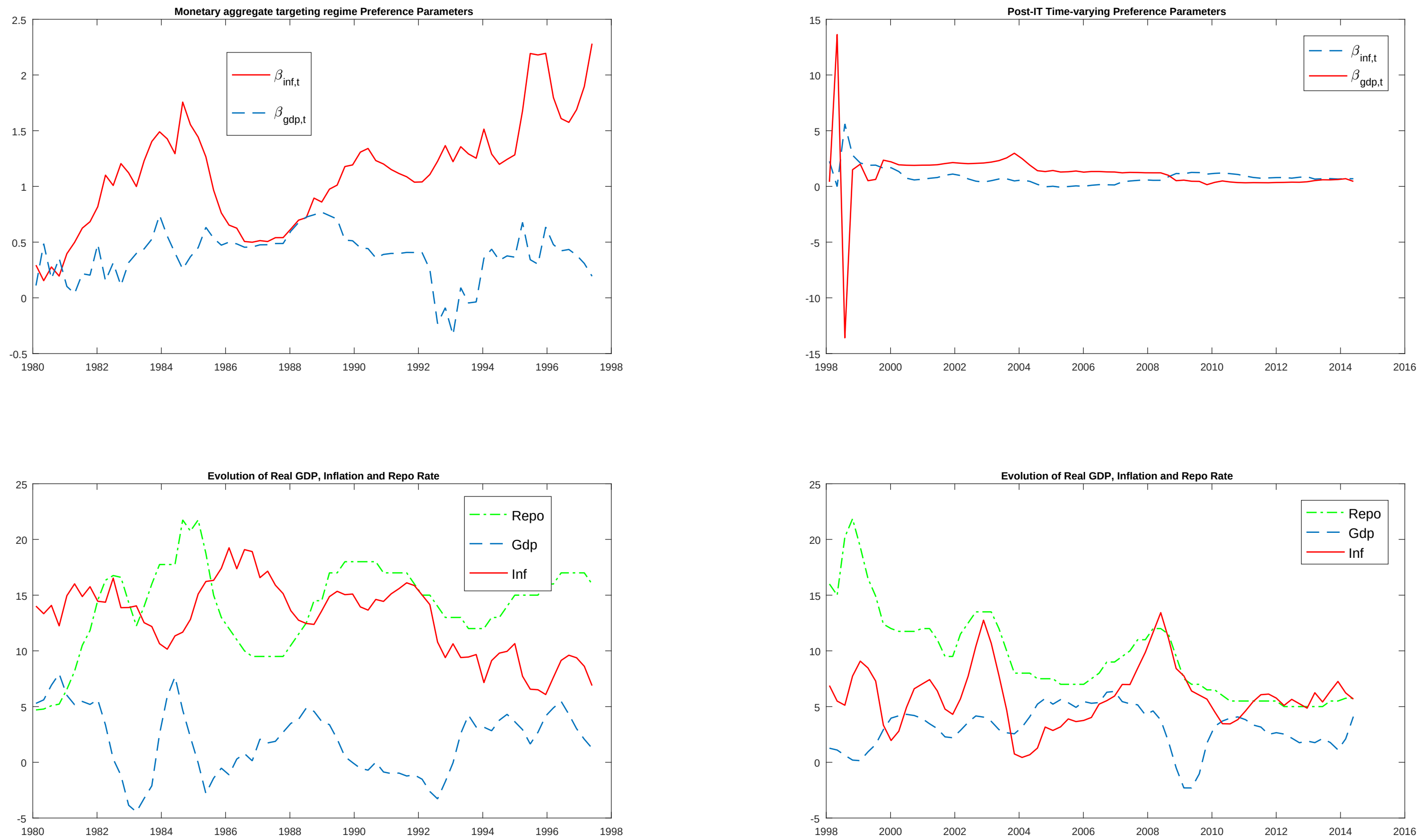


Figure 3.4: Policy regimes innovations

Note: Impulse response of inflation, output and repo rate to repo rate shock. Left panel inflation, middle panel real GDP and right panel repo rate

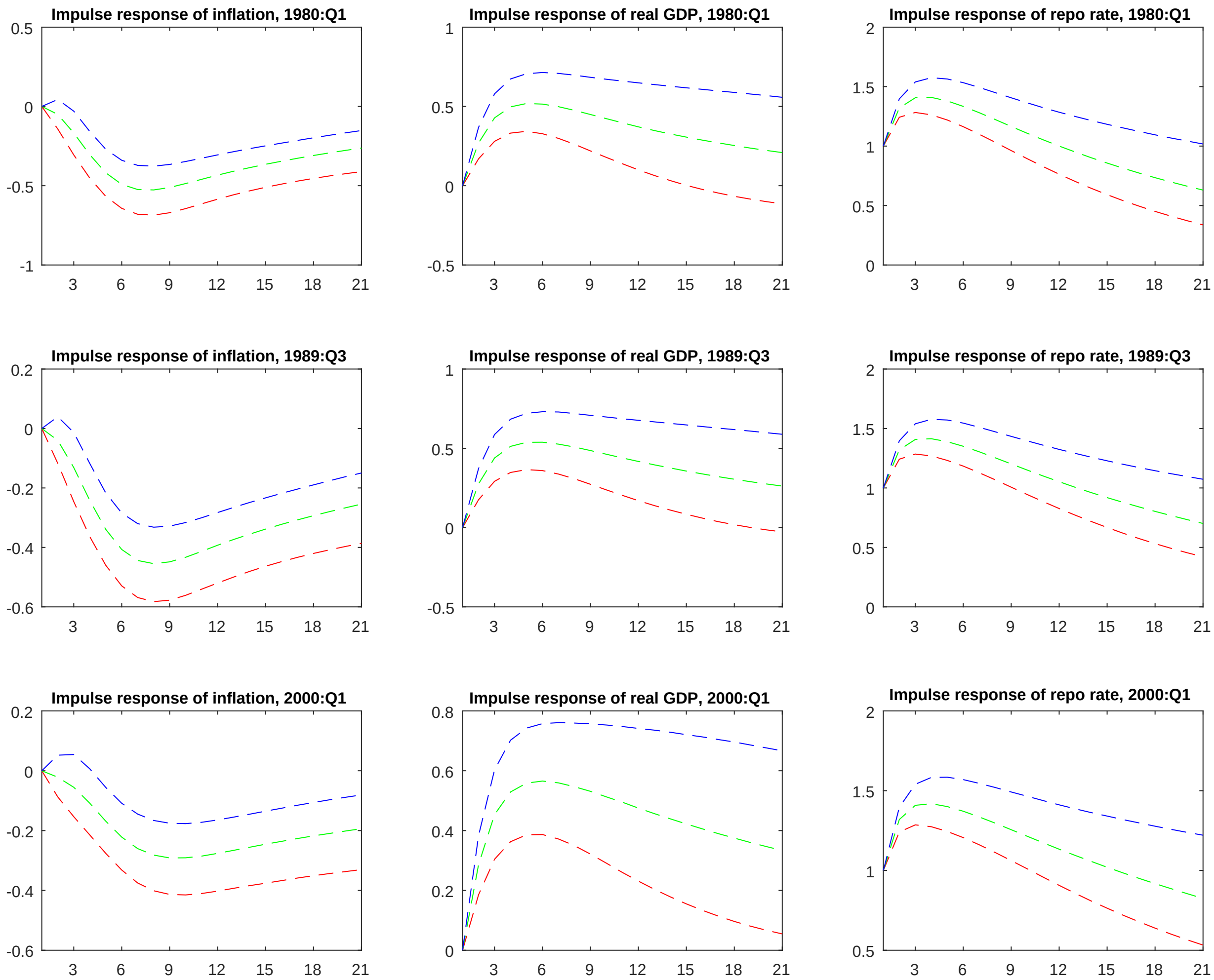


Figure 3.5: Baseline time-varying parameter VAR

Note: Left panel is stochastic volatility of structural innovations and right panel is time-varying dynamic responses

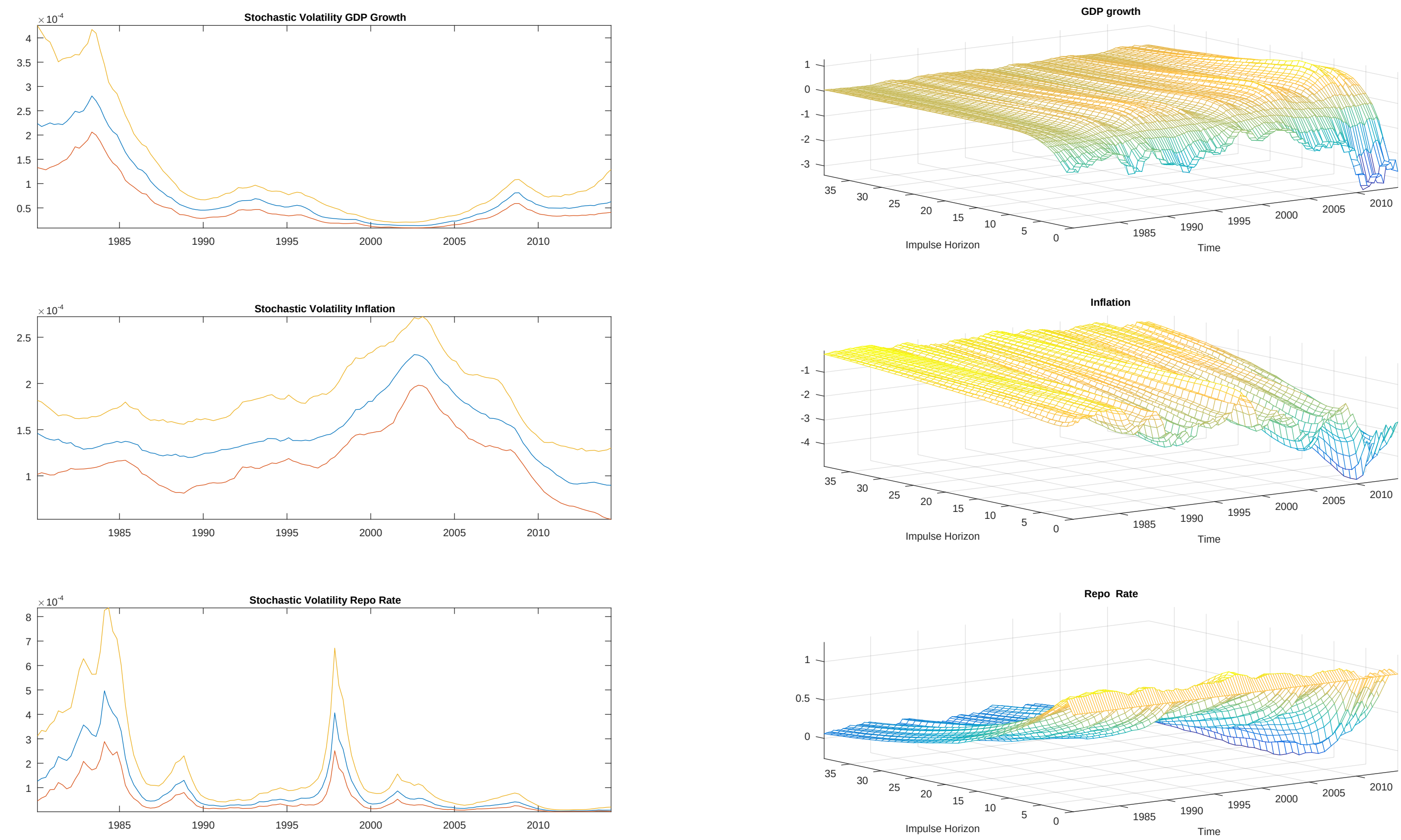
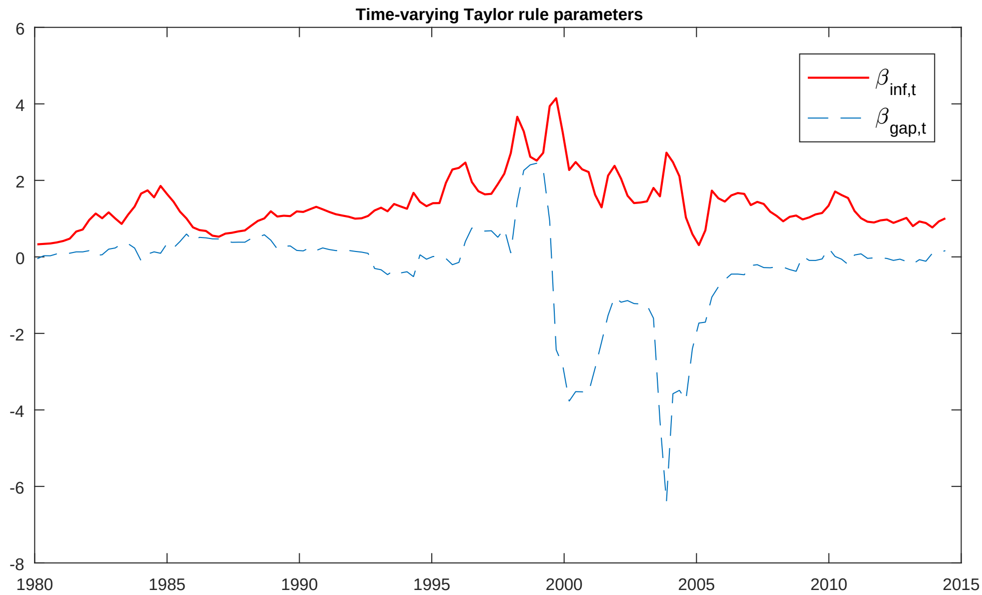


Figure 3.6: Robustness check: Kalman filter estimates of time-varying policy preferences

Note: Top panel is parameter estimates and bottom panel is evolution of observed variables



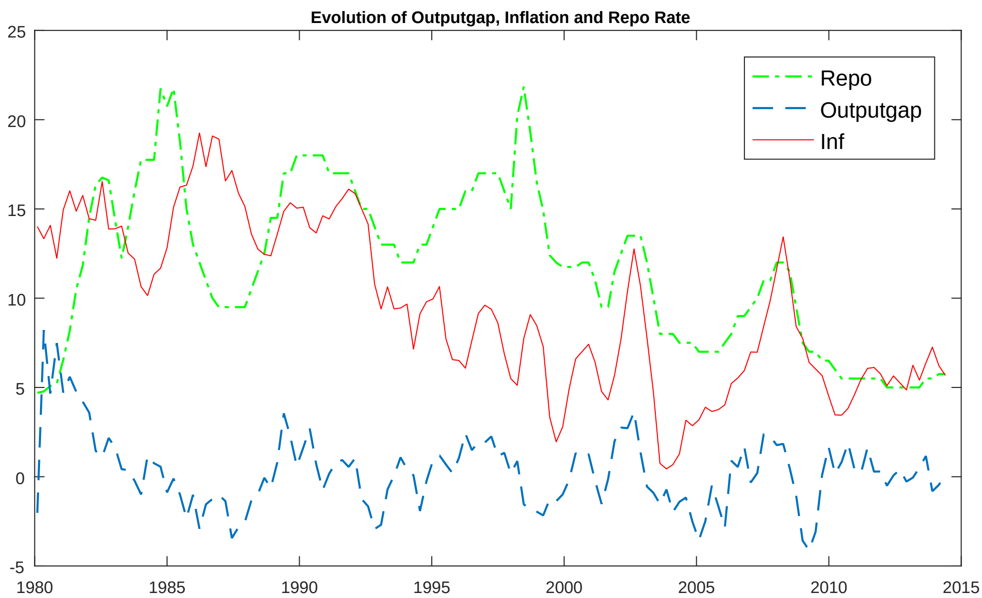


Figure 3.7: Robustness check: time-varying parameter VAR

Note: Left panel is stochastic volatility of structural innovations and right panel is time-vary dynamic responses

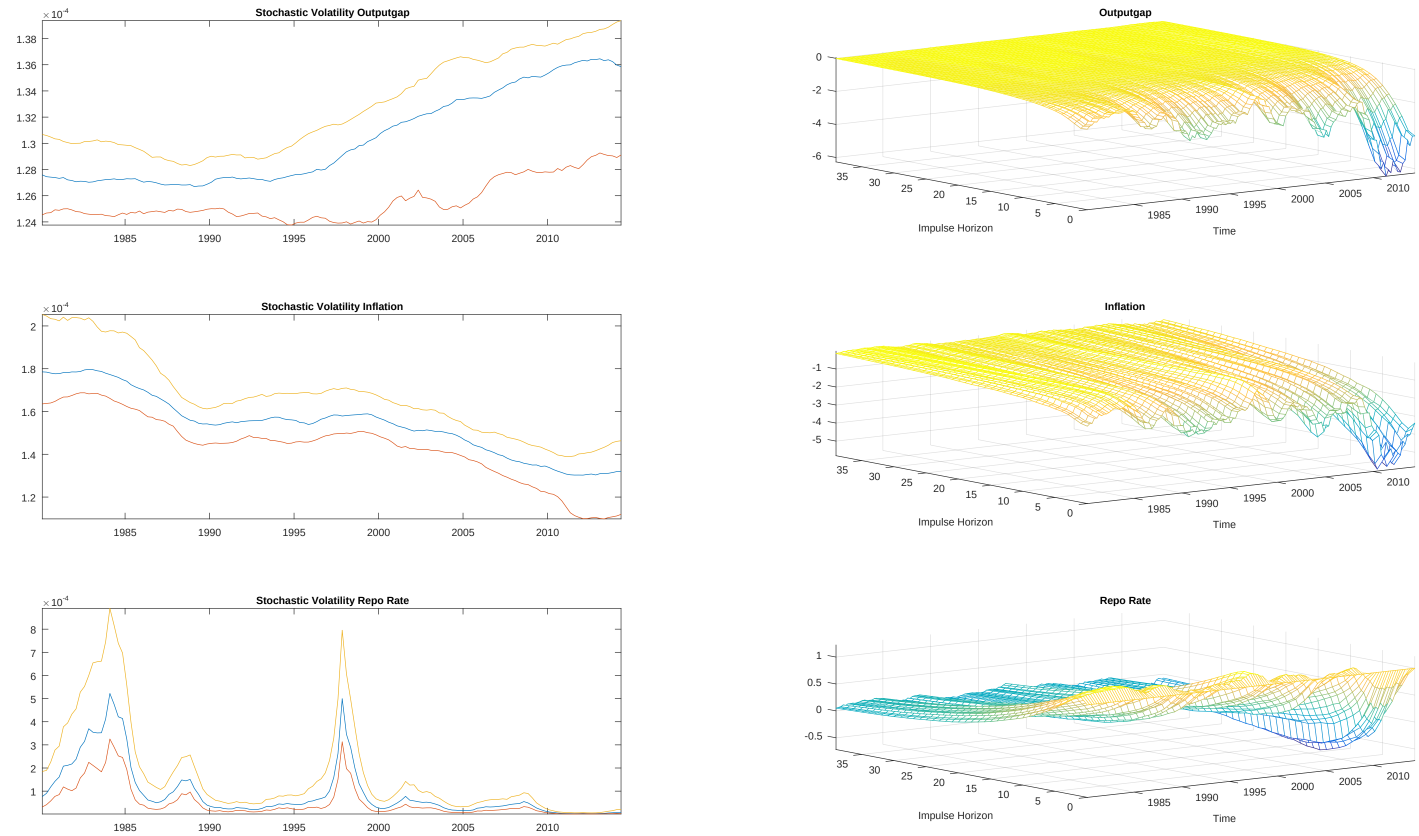


Figure 3.8: Counterfactual simulation of policy preferences, assuming Governor Stals had continued

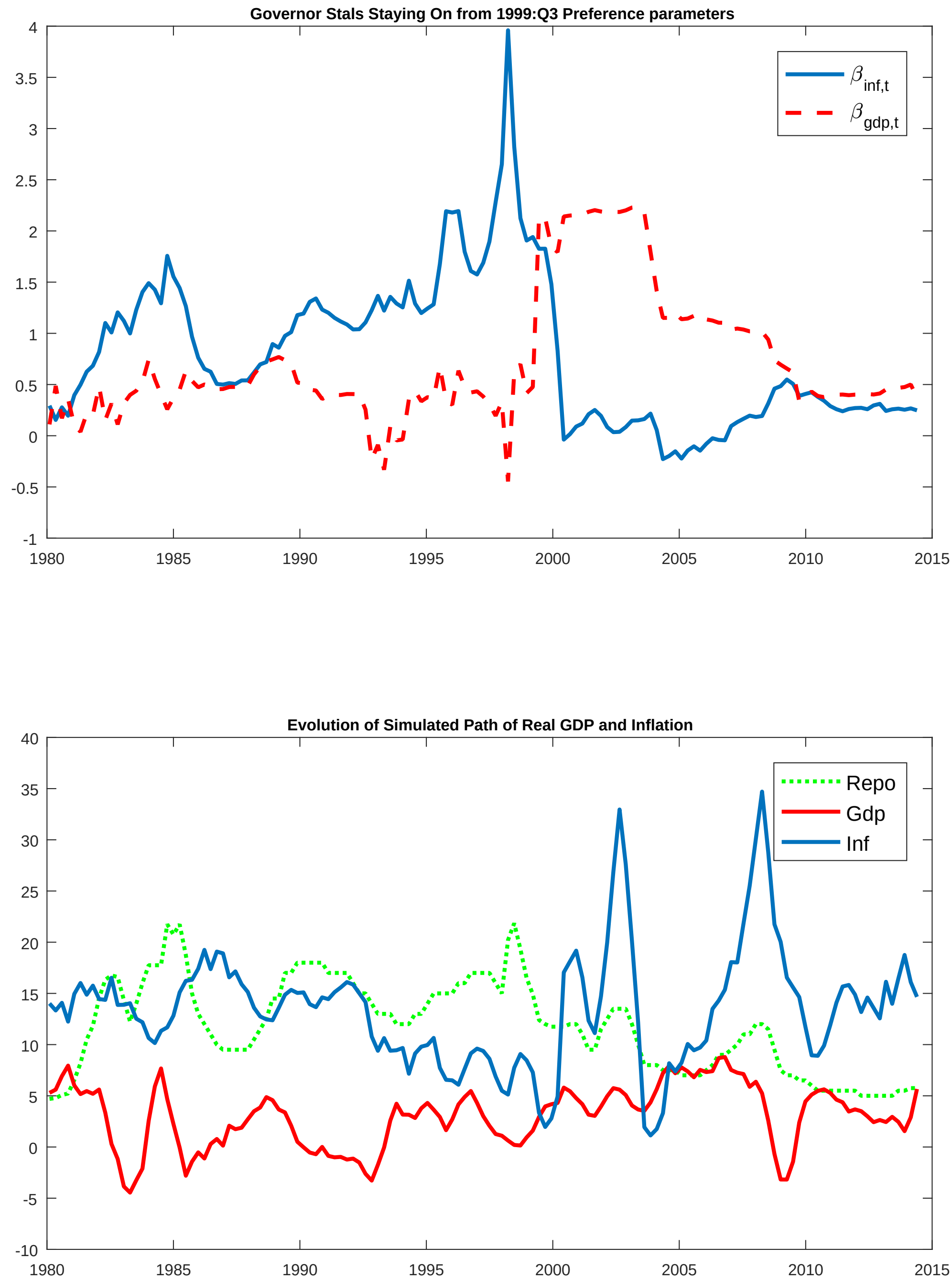


Figure 3.9: Counterfactual simulation of time-varying dynamic responses, assuming Governor Stals had continued

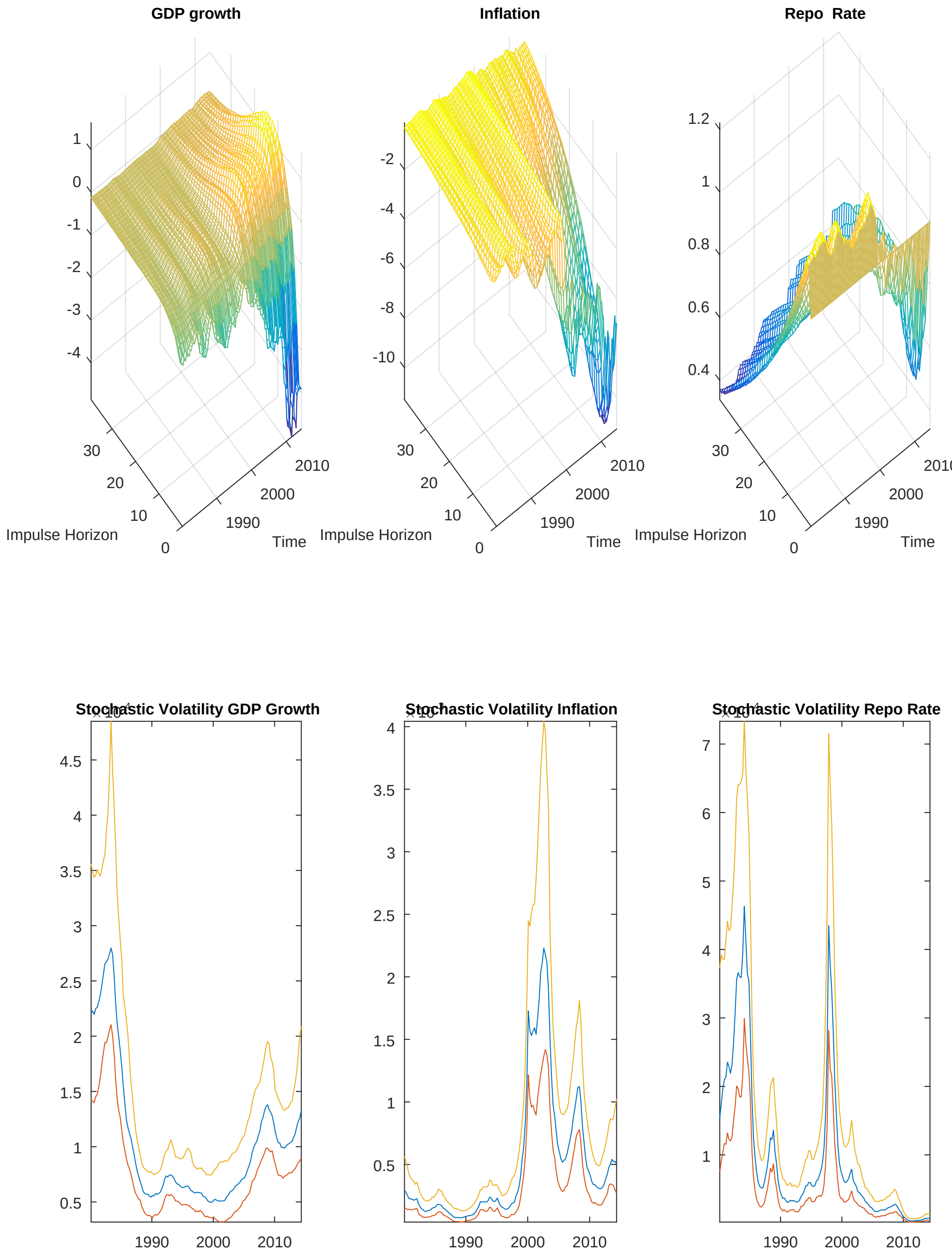
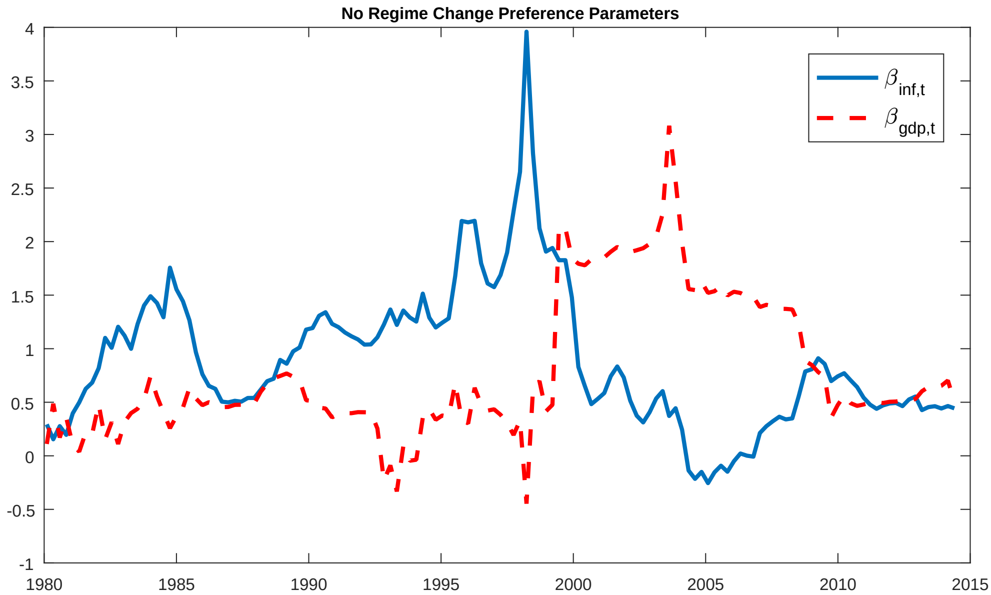


Figure 3.10: Counterfactual simulation of policy preferences, assuming no monetary policy regime change



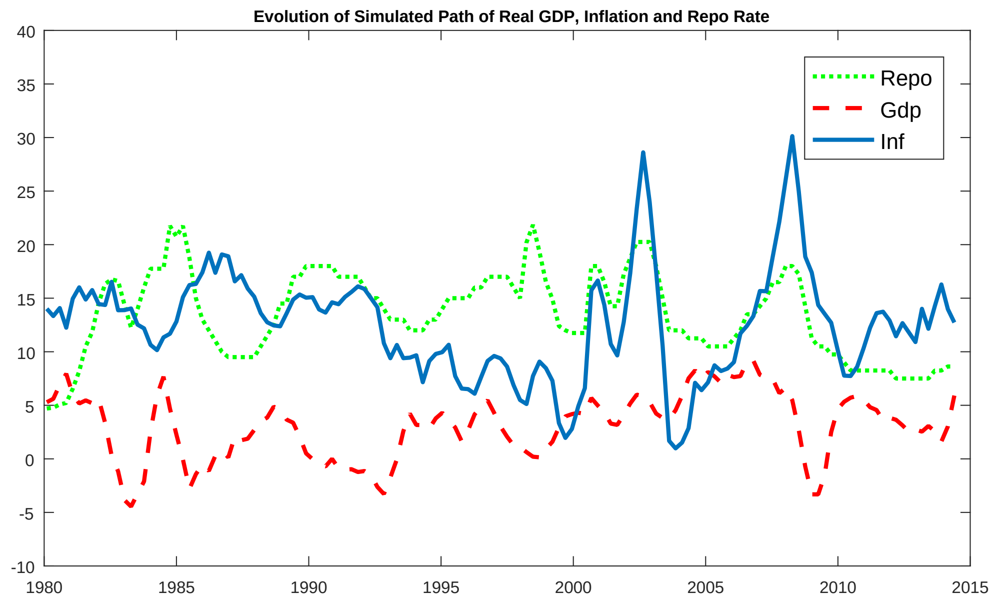


Figure 3.11: Counterfactual simulation of time-varying dynamic responses, assuming no monetary policy regime change

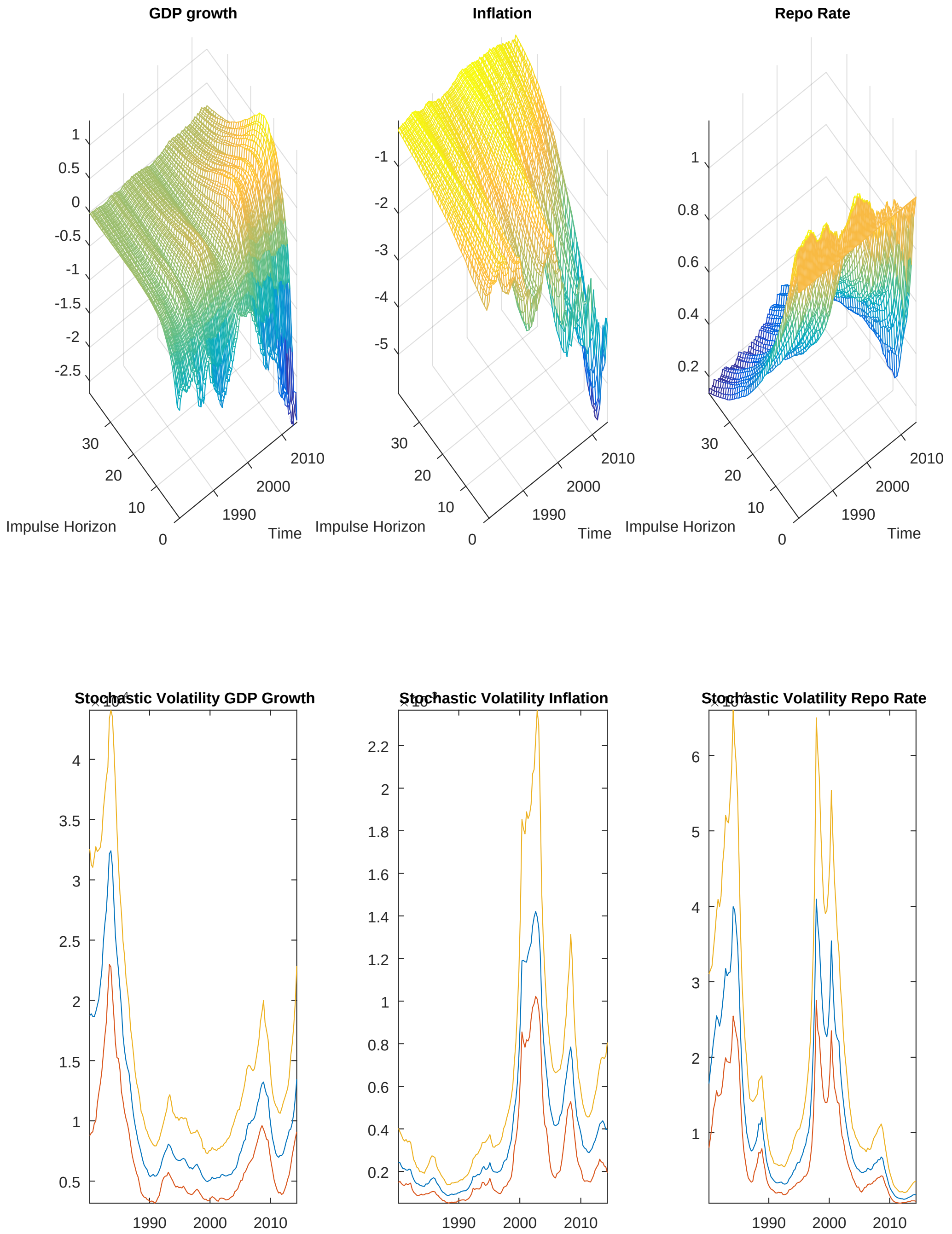
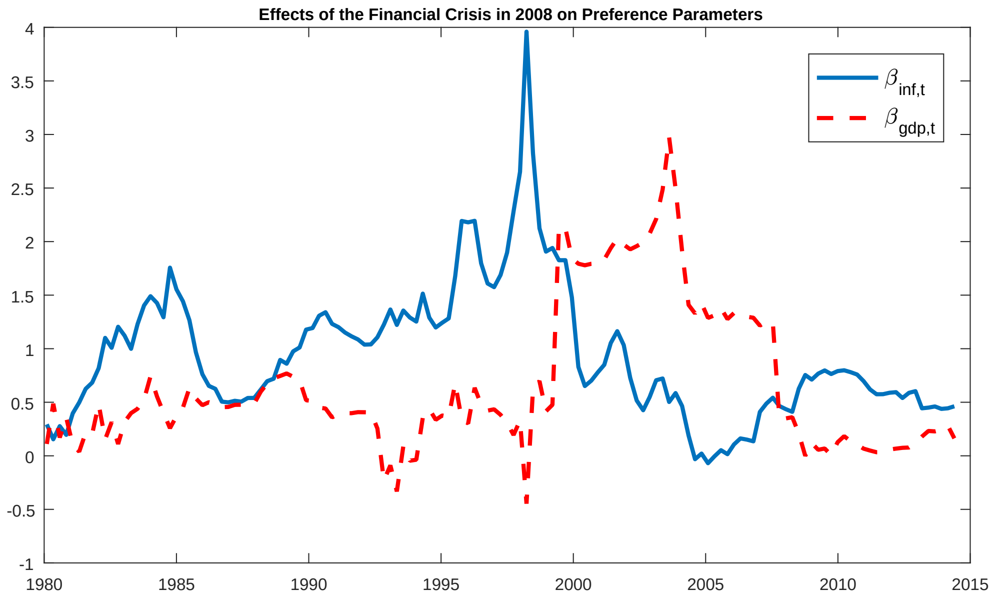


Figure 3.12: Counterfactual simulation of policy preferences, assuming SARB had not responded to the financial crisis



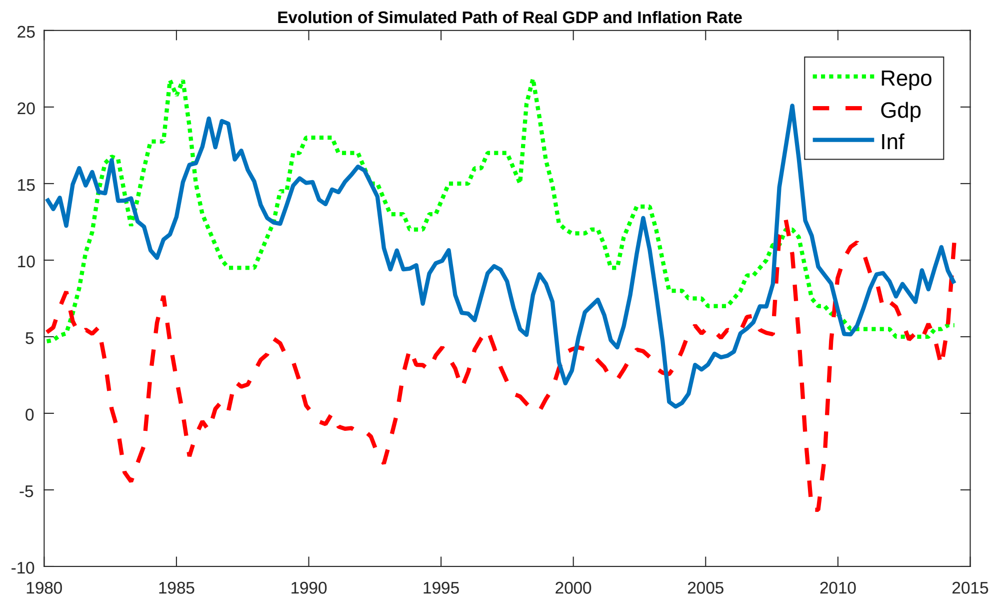


Figure 3.13: Counterfactual simulation of time-varying dynamic responses, assuming SARB had not responded to the financial crisis

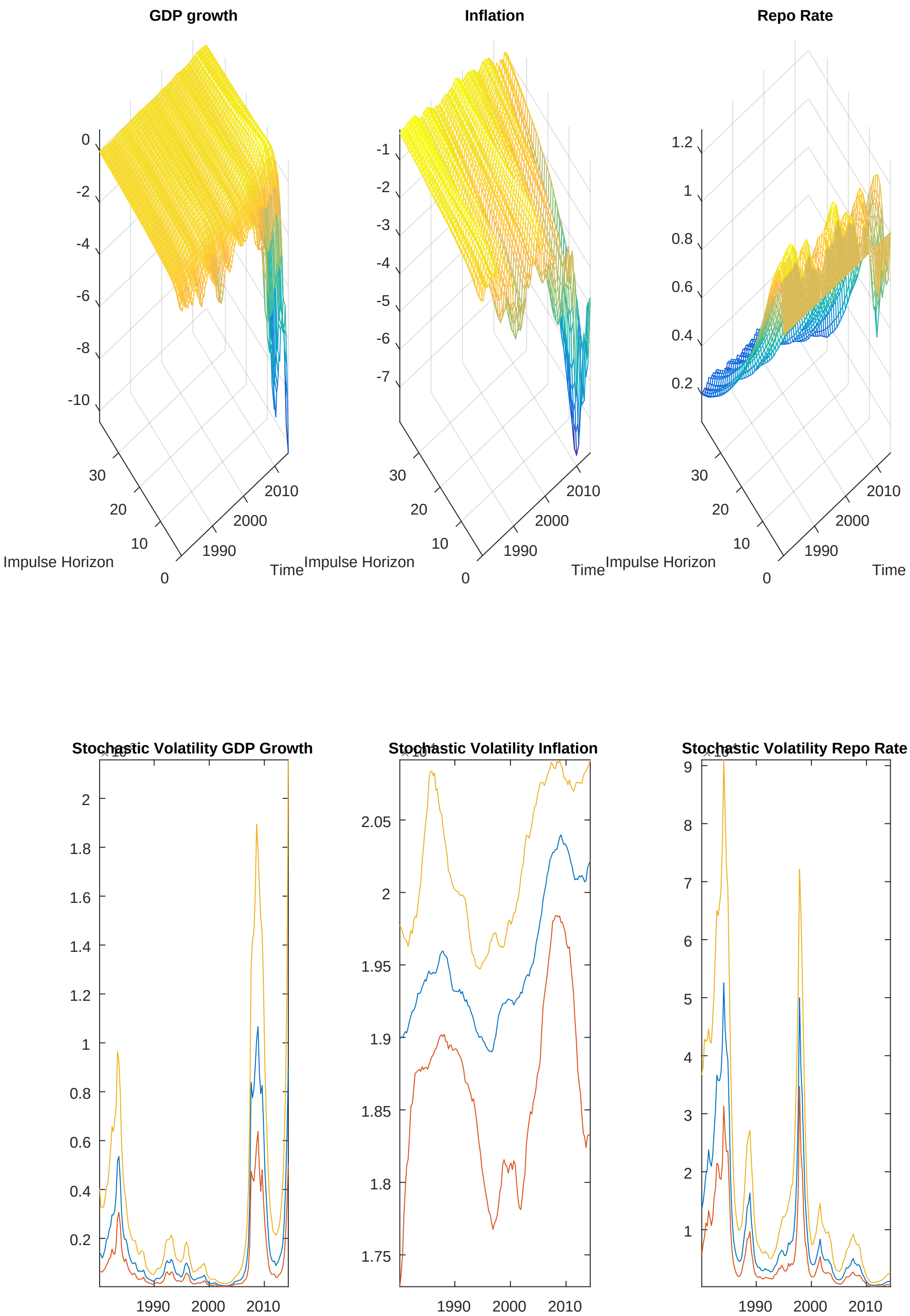
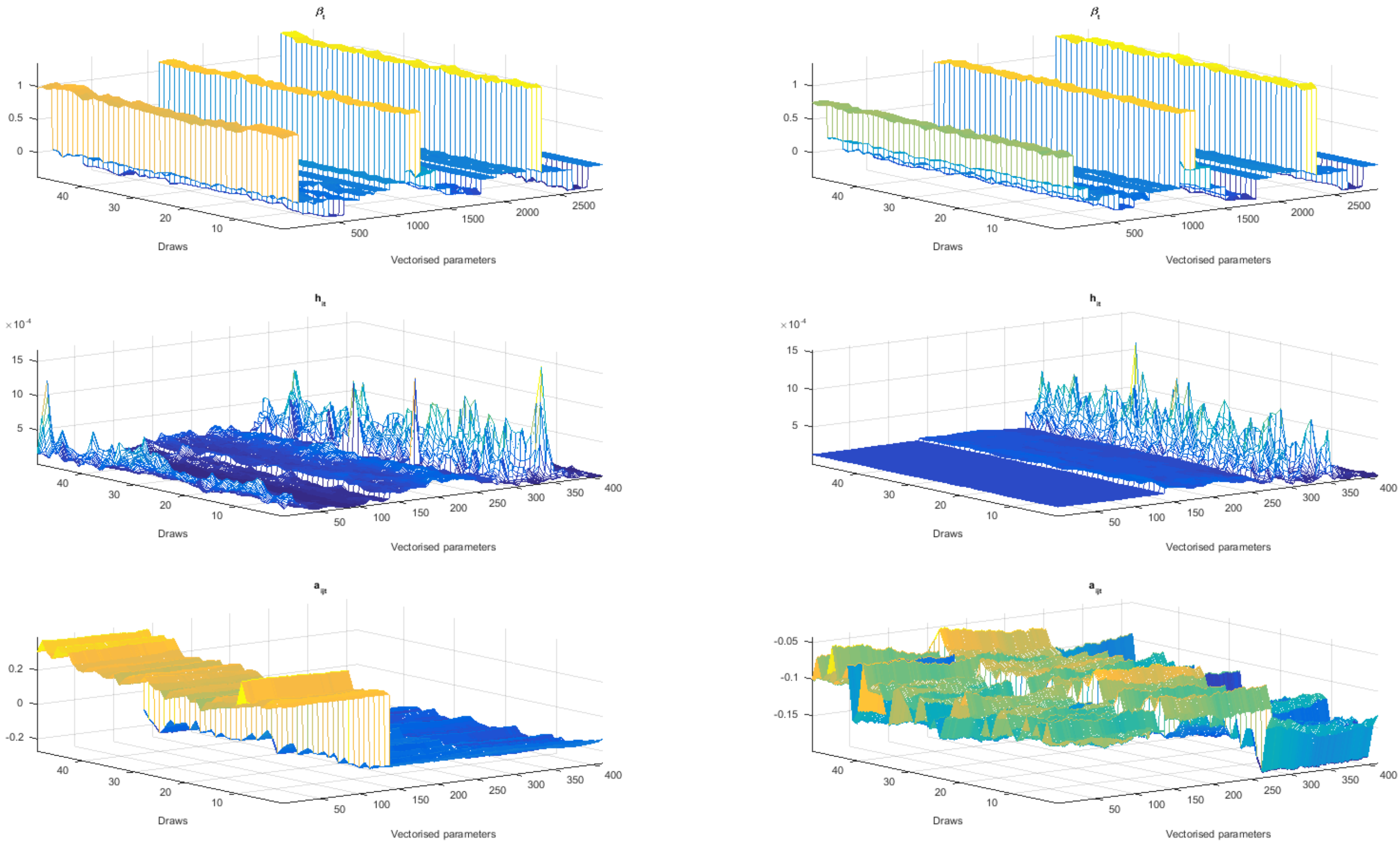


Figure 3.14: Recursive means for the key policy parameters

Note: Left panel real GDP growth rate and right panel output gap



Chapter 4

Policy Regime Switches and Evolution of Macroeconomic Outcomes

4.1 Introduction

In chapter three, the questions to whether central bank preferences are associated with policy regime changes were examined within a time-varying parameter approach. The results show that the estimated central bank policy parameters exhibit gradual changes before and after an inflation targeting regime. This outcome points to some possible parameter instability and nonlinearity in policy authority preferences. To investigate this issue more comprehensively, this chapter examines the effects of policy regime switches on some of the potential sources of macroeconomic fluctuations within a Markov-switching DSGE model.

One strand in the monetary policy literature seeks to understand the main sources of variability in inflation and output from its steady state. Identifying these sources remain a challenge as a result of the changing structure of the economy, changing policy framework, changing volatility and structural breaks in macroeconomic data. Despite this, monetary policy regime changes have been well documented over the last two decades. In the existing literature, thus, two views have gained prominence, that is, good luck and good policy.

According to the good luck view, vector autoregressive technique analyses of policy regimes support a stable economic environment which helps to stabilise inflation and output volatility. Thus, during a period of low inflation, the global economy experienced minimal shocks and these coincide with trade openness in the domestic economy.[1] On the contrary, the good policy view argues that institutional changes, sound monetary policy, such as an inflation targeting regime and some economic theory are responsible for low volatility in inflation and output.[2]

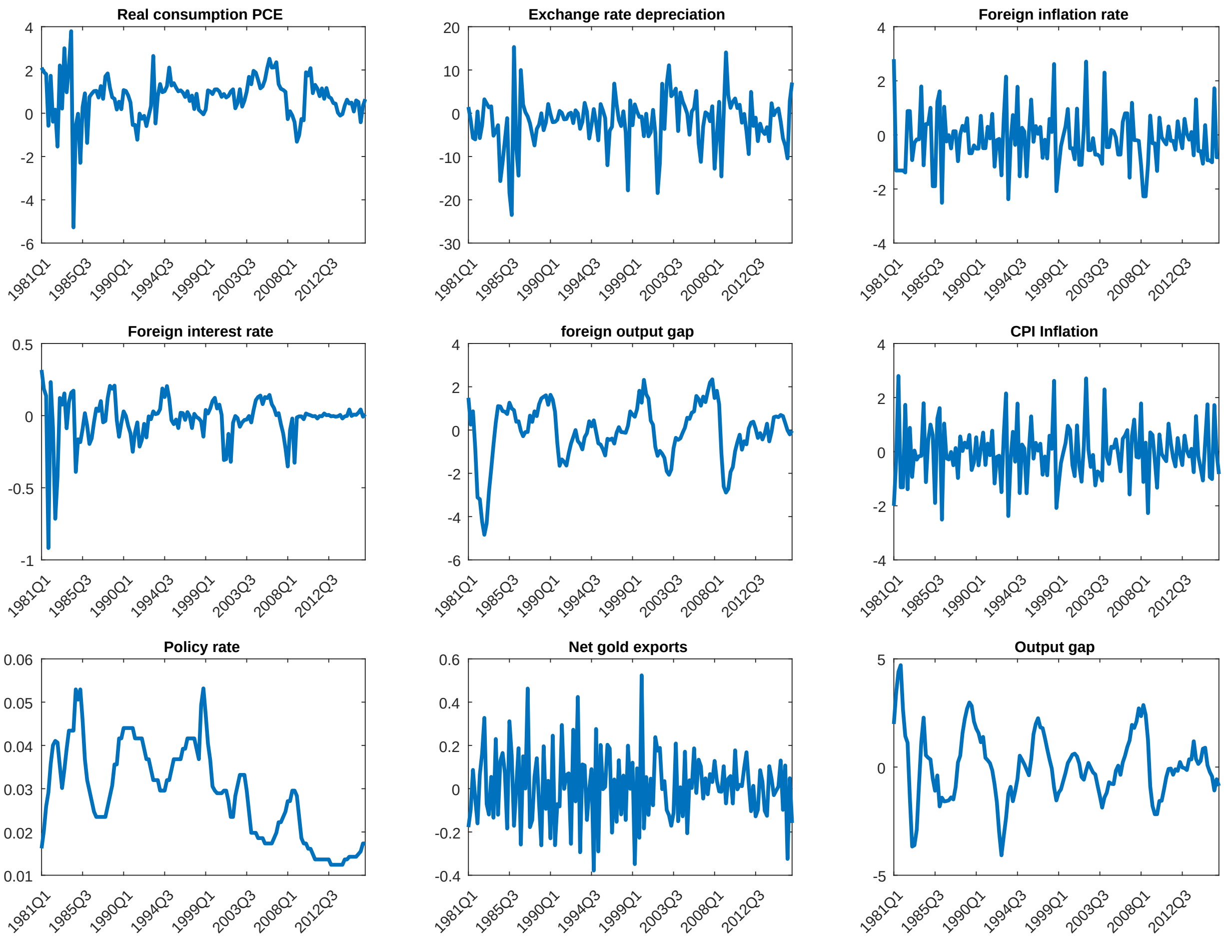
While these studies allow for changes in policy preferences and innovations compared to traditional econometric methods such as OLS and GMM, it does not allow for expectation formations that are likely to affect the current decision-making behaviour of private agents. As a result, Blake and Zampolli (2006), Liu and Mumtaz (2011), Davig and Doh (2014) and Foerster (2014) use Markov-switching rational expectations models to examine multiple regime shifts. The key finding of the above studies is that expectations of future policy regime shifts have significant effects on macroeconomic outcomes. In South Africa, Balcilar et al. (2016) use the Markov-switching DSGE model to forecast structural changes in the South African economy. According to them, the risk-premium shocks have a larger impact on output, inflation and interest rate, whereas policy shock affect only inflation. Similarly, the model with switching properties better fit the economy.

An exploratory analysis of the key macroeconomic variables in the South African economy indicates that there are spikes in the data. Figure 4.1 exhibits considerable changes in the consumer price index inflation, output gap, and policy rate after the adoption of monetary aggregates regime in 1986.

[1]See, Bernanke and Mishkin (1997), Sims and Zha (2006), Mishkin and Schmidt-Hebbel (2007) and Boivin et al. (2010).

[2]This includes, among others, Fuhrer and Olivei (2010), Canova and Ferroni (2012) and Baxa et al. (2014).

Figure 4.1: Observed variables use in this study



The other variables, such as real consumption and the exchange rate also witnessed various upswings and downswings. Gold exports followed with erratic swings that are expected to affect South Africa's macroeconomic performance. When the South African Reserve Bank officially adopted inflation targeting in 2000, the policy rate experienced remarkable reduction and then stabilised in 2005. It rose in 2008 during the global financial crisis, as shown in Figure 4.1. Therefore, the question that emerges is: do the changes in policy preferences explain changes in inflation and output fluctuations? If these are positive, then how do the variances in policy shocks impact on macroeconomic variables?

These questions motivate an examination as to whether the South African economy is characterised by policy regime changes using a regime-switching small open economy dynamic stochastic general equilibrium (DSGE) model. This helps to identify how policy regime changes have affected macroeconomic dynamics in South Africa. The effects of primary commodity export shocks on macroeconomic outcomes, such as inflation, output and policy rate are also addressed. Here, the role of primary commodity exports is incorporated, first, in the form of gold exports, then a merchandise exports. This, therefore, determines the changes to the dynamic responses of the variables in the system. This deepens the understanding of policy regime shifts on macroeconomic performance in small open economies that export primary commodities.

Although Blake and Zampolli (2006), Liu and Mumtaz (2011), Alstadheim et al. (2013), and Bianchi et al. (2014) allow for changes in policy shocks and transition probabilities in their analysis, this chapter differs because it allows for primary export innovations in a regime dependent framework. This is relevant for this study, because one of the factors accounting for low growth in emerging economies, especially South Africa, is weak global demand and lower prices of key export commodities, such as gold, copper, iron and platinum (SARB (2016)). Most literature neglects the role of primary commodity exports within a setup of policy regime switches, either for small developed economies or in emerging economies (see Seoane (2011), Alstadheim et al. (2013), Blagov (2016) and Gonçalves et al. (2016)).

This chapter follows Nimark (2009) and uses a structural small open economy model that characterises the salient features of the South African economy. However, the Taylor-type rule in Nimark (2009) model is modified to account for the exchange rate disconnect puzzle and then Markov-switches are introduced into the model. This model is solved using Maih (2015) efficient perturbation algorithm and carrying out Bayesian inference with data covering the period 1981:Q1 and 2016:Q3. In summary, the study finds that an increase in external shocks and its volatility have a larger role to play in monetary policy analyses in emerging economies compared to only using policy shocks and its volatility. The results suggest that volatilities in structural innovations are the main drivers of economic performance and better fit the economy. Moreover, the model that includes primary commodity export sector shocks in the form of gold exports outperforms the ones that do not capture commodity export shocks. Another result is that the structural parameters are not constant. Following a change in the variances of the structural innovations, the parameters of the structural model keep shifting. This result is related to the views of Fernández-Villaverde et al. (2007), who suggest that there is evidence of parameter drifting in the structural model over their sample period.

The rest of the chapter is structured as follows. In sections two and three, related literature and modeling strategy are provided. Outlined in section four is a regime-switching DSGE environment that includes a generic framework, stability solution and estimation methods, as well as data, priors and number of Markov switches in this model. In section five, the empirical results are provided. This is followed by the conclusion of the discussion in section six.

4.2 Literature Review

This chapter is related to parameter instability literature of dynamic stochastic general equilibrium models. This strand of the literature includes early research by Laforte (2005), Rubio-Ramirez and Fernéndez-Villaverde (2007) and Justiniano and Preston (2010), who use DSGE models with stochastic volatility in the structural innovations. They find considerable evidence that the parameters are nonconstant. Castelnuovo et al. (2014) examine policy regime swtiches and time-varying inflation trends with volatility shocks in a unifying model. According to them, a time-varying policy switching model is more tractable as compared to a constant policy regime model. Related findings are documented in Ferman (2011), Bianchi et al. (2014) and Debortoli and Nunes (2014).

Alstadheim et al. (2013) recently considered a Markov-switching DGSE model that endogenises the nominal exchange rate. They solve the model using a perturbation method and carry out estimations through Bayesian inference. According to them, the magnitude of policy shocks and structural parameters in relation to Canada, Norway, Sweden and the U.K. vary over their sample period. Similarly, Chen and MacDonald (2012) used U.K. dataset over the past 35 years to examine changes in the economy using a Bayesian technique. In their paper, they find that policy rule parameters, price indexes, and exogenous shocks experience major variations.

These studies have convinced the writer that policy regime switches are an important characteristics of macroeconomic data. However, the studies by Alstadheim et al. (2013) and Chen and MacDonald (2012) use Lubik and Schorfheide (2007) model, whose features are restrictive in nature to characterise emerging economies. The model assumes the existence of a complete financial market and with minimal shocks. Therefore, a structural small open economy model that characterises the features of emerging economies to quantify the effect of policy regime switches is required. This thesis's contribution to this literature is the introduction of shocks unique to the South African economy that depends on primary commodity exports with incomplete financial market. This could also apply to other emerging economies.

In emerging economies Seoane (2011) uses a Markov-switching DSGE model to examine the effectiveness of fiscal and monetary policy, and Blagov (2016) investigates the sensitivity of a currency board and policy credibility of the Estonia policy authority. Seoane (2011) finds that an active monetary policy in the 1980s and 1990s lasted in short periods of a two-year interval in instances when there was an economic crisis. Consequently, a policy shift from active fiscal policy to active monetary policy resulted in high output losses. Blagov (2016) finds that a stable currency board helps mitigate the adverse effect of risk premia in the long run. It is important to note that these studies do not consider policy regime switches with a primary commodity export sector that is essential in emerging economies. This chapter fills the gap in this part of the literature.

This thesis is related to studies that look at the literature that examines central bank responses to inflation, output and exchange rate in South Africa. This includes Steinbach et al. (2009), Alpanda et al. (2010) and Peters (2016). According to them, the SARB does not attach significant weight to the exchange rate, instead it attaches greater weight to inflation variability relative to output. Although these results are encouraging, they are based on a constant parameter assumption that may show bias in their results. Nevertheless, during certain regimes policy innovations may change, which may influence the dynamics of macroeconomic outcomes. For these reason this chapter revisits these studies to establish whether in a regime-dependent state the SARB policy conduct is different from their findings.

The method used in this chapter is an algorithm that is related to the solution methods of Davig and Leeper (2007), Foerster et al. (2014), Farmer et al. (2015), Maih (2015) and Bianchi and Melosi (2016). Bianchi and Melosi (2016) derive a solution method for rational expectation models that agent beliefs are subject to varying states, such as good, bad and uncertain states that impact on macroeconomic performance. According to them, the algorithm is superior because it can account for slow and sudden changes in agent beliefs and uncertainty. In this thesis the efficient perturbation algorithm of Maih (2015) is followed because it is superior in solving log-linearised rational expectations models. More importantly, this solution method identifies sufficient conditions for determinacy in a mean square stability of rational expectations models. This is different from Davig and Leeper (2007) and Farmer et al. (2015) solution methods that generate multiple equilibria. This algorithm captures forward, current and lagged variables in the model.

4.3 Modeling Strategy

4.3.1 Model Characteristics

The model setup used here is adopted from Nimark (2009), a structural small open economy model applied to the Australian economy. This model is, however, presented somewhat differently in this work, for the monetary policy rule is allowed to account for the exchange rate that is a major characteristics of the South African economy. This model has three properties that satisfy the requirements needed to address the questions set out in this chapter. First, the South African economy is described as a structural small open economy. Secondly, the model theoretical framework is simple to follow and provides for adequate dynamics to empirically test important monetary policy theses. Thirdly, a number of frictions are introduced in domestic and imported goods inflation and consumer utility function, as well as exogenous export demand shocks to characterise the South African economy and risk premia shocks to induce a smooth steady state.

Further, this model accounts for primary commodity exports sector and foreign shocks to the domestic economy. These features describe the South African economy as a price taker in its primary commodity exports in the international market. In South Africa, merchandise trade is driven by primary commodities that constitute more than half of exports while half of imported goods are manufactured goods.[3]

There are four economic agents in this model, namely the policy authority, aggregation sectors, representative consumers and the rest of the world. The policy authority sets the policy rate to follow a Taylor-type rule. The nominal exchange rate depreciation is introduced in the representative consumers' budget constraint through the international securities market. In addition, the exchange rate affects commodity exporters via the world relative prices of primary commodity exports channel and profits of firms that import goods.

The aggregators consist of domestic producers, importers and primary commodity exporters. The domestic producers produce differentiated goods in a monopolistically competitive market. The goods can be exported or sold in the domestic market. In this case, firms charge a mark-up over marginal cost as a result of consumer preferences for different bundles of goods and some market power over the price of goods firms sell. In this model, the commodity export demand sector is characterised by exogenous export shocks and export income shock steming from a variablility in world commodity prices.

Representative consumer preferences are governed by domestic and imported production goods as well as labour supply. The rest of the foreign economy is large and is considered exogenous to the domestic economy.

4.3.2 Extract of the Model

In what follows, the important parts of the log-linearised model that are relevant to this study are provided.[4] In this model, the primary commodity export demand sector is given in eq. (4.1) as

$$xe_t = y_t^{fy} - \delta_e pw_t + ze_t, \tag{4.1}$$

[3]http://tradestats.thedti.gov.za/ReportFolders/reportFolders.aspx

[4]See, detailed derivations are provided in Nimark (2009).

where $[xe_t,\ y_t^{fy},\ ze_t]$ are total primary commodity exports, foreign output and commodity exports shock process, respectively. δ_e is price elasticity of commodity export demand and pw_t is relative prices of world primary commodity exports which takes the form

$$pw_t = \pi_t - \pi_t^{fi} - \Delta s_t + pw_{t-1}, \tag{4.2}$$

where $[\pi_t,\ s_t,\ \pi_t^{fi}]$ are consumer price index inflation, terms of trade and foreign inflation rate. The shock to commodity export income equation in Nimark (2009) is shut due to computational complexity.

Regarding monetary policy, the policy authority sets a Taylor-type rule that takes into account exchange rate deviations to address the exchange rate disconnect puzzle.[5] In this way, this chapter departs from Nimark (2009) setup of the policy rule that does not account for the nominal exchange rate depreciation.

$$r_t = \rho_r r_{t-1} + (1-\rho_r)[\gamma_1\pi_t + \gamma_2 y_t + \gamma_3\Delta e_t] + \sigma^{er}, \tag{4.3}$$

where $[r_t,\ e_t,\ \sigma^{er}]$ are policy rate, nominal effective exchange rate depreciation and policy rate shocks. The parameters $[\rho_r, \gamma_1, \gamma_2, \gamma_3]$ control the degree to which policy rate adjusts to interest rate smoothing, deviations in consumer price index inflation, the output gap, and the nominal exchange rate. These show that the interest rate smoothing term in the policy rule ranges $[0 < \rho_r < 1]$ and the policy rule parameters ranges $[\gamma_1, \gamma_2, \gamma_3 \geq 0]$.

In eq. (4.3), y_t is domestic output that links both the direct effect from the terms of trade and an indirect effect that operate through the market clearing condition given in eq. (4.4) as

$$y_t = (1-\alpha)c_t + \alpha[\omega(s_t + q_t) + y_t^{fy}], \tag{4.4}$$

eq. (4.4) is made up of domestic consumption (c_t), terms of trade (s_t), real exchange rate (q_t) and foreign output, while ω is the elasticity of substitution between

[5]The exchange rate disconnect puzzle refers to the missing link between the predictability of the exchange rate and some key economic fundamentals, such as output growth, interest rates, relative prices, forward rates and money.

home and foreign goods and α is the share of foreign goods in consumption.

In this model, the uncovered interest rate parity condition is similar to Schmitt-Grohé and Uribe (2003) and Justiniano and Preston (2010). They motivate an imperfect international securities market between foreign and domestic bonds, thus the uncovered interest rate parity condition is as follows in eq. (4.5)

$$q_t = q_{t+1|t} - (r_t - \pi_{t+1|t}) + (r_t^{fr} - \pi_{t+1|t}^{fi}) + \kappa b_t + zq_t, \tag{4.5}$$

where $[r_t^{fr}, b_t, \kappa, zq_t]$ are foreign interest rate, net foreign debt position, debt elasticity with respect to interest rate risk premia and risk premia shock process.

The Euler equation is given in eq. (4.6) as

$$c_t = \frac{\lambda}{1+\lambda} c_{t-1} - \frac{1}{1+\lambda} c_{t+1|t} - \frac{1-\lambda}{\tau(1+\lambda)} (r_t - \pi_{t+1|t} + zd_t), \tag{4.6}$$

where $[c_t, zd_t]$ are real household consumption and preference shock processes. $[\lambda, \tau]$ are the degree of habit formation and elasticity of intertemporal substitution.

The Philips curve for domestic inflation is of the form;

$$\begin{aligned} \pi_t^h = {} & \frac{\delta_h}{1+\beta\delta_h}\pi_{t-1}^h + \frac{\beta}{1+\beta\delta_h}\pi_{t+1|t}^h + \frac{(1-\phi_h)(1-\phi_h\beta)}{\phi_h(1+\beta\delta_h)}[\psi * y_t - (1+\psi) * zp_t + \alpha * s_t \\ & + (\frac{\tau}{(1+\beta*\delta_h)*(1-\lambda)})(c_t - \lambda * c_{t-1})], \end{aligned} \tag{4.7}$$

where π_t^h is domestic inflation and zp_t is the technology shock process. The structural parameters are δ_h—price index for home-produced goods, and ϕ_h—price adjustment cost for home-produced goods. β is the representative consumers' subjective discount factor and ψ is the inverse elasticity of labour supply.

The Phillips curve for imported inflation takes the form;

$$\pi_t^f = \frac{\delta_f}{1+\beta\delta_f}\pi_{t-1}^f + \frac{\beta}{1+\beta\delta_f}\pi_{t+1|t}^f + \frac{(1-\phi_f)(1-\phi_f\beta)}{\phi_f(1+\beta\delta_f)}[q_t - (1-\alpha)s_t] + zs_t, \tag{4.8}$$

where π_t^f represents imported inflation and zs_t is the import-cost inflation shock process. δ_f is a fraction of importing firms that reset prices according to Calvo (1983) pricing. When a fraction of firms do not adjust prices, δ_f tends to 0, then deviations from the law of one price becomes smaller. ϕ_f is a fraction of importers that do change prices while the other fraction $(1-\phi_f)$ uses the rule of thumb price setting. Therefore, the consumer price inflation is given in eq. (4.9) as

$$\pi_t = \alpha\pi_t^h + (1-\alpha)\pi_t^f. \tag{4.9}$$

The rest of the foreign economy variables [y_t^{fy}, r_t^{fr}, π_t^{fi}] follow autoregressive processes of order one [AR(1)]. In this model, the innovations of interest are nine and evolve as AR(1) processes. These include monetary policy shock, preference shock, technology shock, imported cost inflation, export shock, risk premia shock, foreign interest rate shock, foreign inflation shock and foreign output shock. The rest of the model equations are presented in Table 4.5 of Appendix A 4.7.1.

Regime switches are introduced into eqs. (4.1) to (4.9), the remaining equations in Table 4.5 and all the innovations are regime-dependent.

4.4 A Regime-Switching DSGE Environment

This section provides a generic framework, solution method and estimation strategy of a regime-switching DSGE model. The estimations in this thesis are carried out through RISE, a MATLAB package that has been designed to solve and estimate regime-switching DSGE models.[6] This environment characterises a rational expectation model in which changes in policy parameters are allowed to influence the formation of expectations by private agents. When policy regime changes over time, the regime-switching rational expectations model allows private agents to take those changes into account. A simple conjecture is that if a cental bank reacts more aggressively to inflation, private agents may take into account these expectations about future inflation changes. This information may be able to stabilise inflation and output, even before the actual policy takes effect, because of either wage setting under diferent price expectations or price setting under different marginal cost facing the firm.

[6]RISE refers to the Rationality in Switching Environment software developed by Maih (2015). This package can be obtained from https://github.com/jmaih/RISEtoolbox.

4.4.1 Generic Framework and Solution Method

It is assumed that the variances of all the variables and shock processes follow a regime-dependent state Markov chain parameters (s_t). In this vein, the transition matrix is governed by a benchmark P probability matrix characterised as

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}, \tag{4.10}$$

where $P_{1,2} = prob(s_{t+1} = 2|s_t = 1)$ is transition probability from state 1 to state 2. This follows that the small open economy dynamic general equilibrium model with regime-switching has a state space representation of the form

$$\upsilon \equiv [b_{t+1}(y_{t+1}), f_{t+1}(y_{t+1}), s_t(y_t), p_t(y_t), b_t(y_t), f_t(y_t), p_{t-1}, b_{t-1}, \varepsilon_t, \theta_{y_{t+1}}]^{`}, \tag{4.11}$$

where b_t is an $m_b \times 1$ vector of forward and exogenous variables, f_t is $m_f \times 1$ forward looking variables, p_t is $m_p \times 1$ vector of exogenous variables, s_t is $m_s \times 1$ vector of current variables , ε_t is $m_\varepsilon \times 1$ vector of innovations and $\theta_{y_{t+1}}$ is $m_\theta \times 1$ a vector of the matrices with switching parameters in the model.

Following the seminal contribution of Davig and Leeper (2007), Markov-switching rational expectations research has become a popular field in macroeconometrics.[7] For example, Foerster et al. (2014), Farmer et al. (2015), Maih (2015) and Cho (2016) have found new solution methods to this class of models. Thus, the popular Klein (2000) and Sims (2002) algorithms are no longer suitable to solve this class of models.

This chapter, therefore, uses the solution method developed by Maih (2015).[8] The algorithm is an efficient perturbation method for solving regime-switching rational expectations models that allow one to determine a single equilibrium condition relevant for economic analysis. This is an improvement over the minimal

[7]They find that determinancy condition for regime switching equilibria depend on curent regime and shocks

[8] This model accounts for lagged endogenuous variables and regime switches that depend on current and future regimes. Further, the model is suitable for log-linearised rational expectations models, where private agent parameters are allowed to switch across regimes.

state variable algorithm proposed by Farmer et al. (2015).[9] The efficient perturbation method algorithm is applied on eqs. (4.1)- (4.9) leading to eq. (4.11) to group the parameters into lagged, current as well as forward-looking endogenous and exogenous variables. The next step is to estimate the first-order perturbation solution to yield regime-dependent solution of the form

$$\Upsilon^{y_t} \equiv \Upsilon^{y_t}(\overline{z}_{y_t}) + \Upsilon^{y_t}(z_t - \overline{z}_t), \tag{4.12}$$

where Υ^{y_t} is the approximation rule and $z_t = [p_{t-1}, b_{t-1}, \theta, \varepsilon_t]$ is $m_z \times 1$ vector of state variables. $\overline{z}_t$ is steady state values of the state variables and θ is a vector of the perturbation parameters.

4.4.2 Estimation

The next step in the investigation is the estimation of the observed variables. The estimation strategy is carried out by Bayesian inference through a Markov-Chain Monte Carlo (MCMC). In particular, the random walk Metropolis-Hastings algorithm is used, because in estimating DSGE models some of the conditional distributions are not obtainable in closed form (see Herbst and Schorfheide (2015)). The parameters of the prior distribution are set and a new set of parameters is drawn from the random walk candidate density. Thereafter, the likelihood and the prior distribution at the draw value of the parameters are evaluated with the aim of generating the posterior distribution and estimating the marginal density from the data.

Here the Kalman filter algorithm is not appropriate, so the Kim filter algorithm is adopted. The Kim filter is suitable in a large set of Markov-switching DSGE models to compute the posteriors and marginal densities. The Kim filter is a combination of the Kalman and Hamilton filters, where the possible paths are

[9] Davig and Leeper (2007) and Farmer et al. (2015) solution algorithms generate multiple equilibria in that when one regime produces more volatility relative to the other regime, this results in indeterminacy.

collapsed through averaging at each step of the likelihood (Kim and Nelson (1999)). This keeps the computation of the likelihood tractable.

In all, 20 equations with 51 variables made up of lags, forward looking and current endogenous and exogenous variables were estimated.

4.4.3 Data

In this chapter, nine observed variables at quarterly frequency from 1981:Q1 to 2016:Q3 are used. The sample period was chosen to cover the period prior to the adoption of a monetary aggregates regime in 1986. The domestic observed variables are six, and consist of real GDP seasonally adjusted, real household consumption expenditure seasonally adjusted, gold exports seasonally adjusted as a proxy for primary commodity exports, policy rate(repo rate), consumer price index inflation, and a nominal effective exchange rate. The foreign observed variables relate to the U.S. and are foreign interest rate, foreign output and foreign inflation. The remaining variables in the model are unobserved. CPI inflation, policy rate, foreign inflation, foreign interest rate and foreign output are sourced from IMF International Financial Statistics (IFS) database. The rest of the observed variables are obtained from the South African Reserve Bank database.

Inflation is consumer price index inflation measured on a quarterly basis. The nominal effective exchange rate is quarterly percentage changes in the South African rand measured as a trade-weighted average of twenty major trading partners of South Africa. Regarding foreign interest rate, inflation and output, we use the U.S.-three month Treasury bill, consumer price index inflation and the real GDP seasonally adjusted.

All the series were transformed into their growth rates by taking the natural log difference of the series and multiplying them by 100 to standardise the variables except policy rate and foreign interest rate. The policy rate and foreign interest rate are measured as per cent per annum. These are converted into quarterly averages as $log(1+\frac{policyrate}{400})$. With respect to domestic and foreign output, the output gaps are extracted using the HP filter.

4.4.4 Priors and Markov Switches

This section presents the number of Markov switches introdued into the model and priors of the structural and policy regime switches. In the Markov switches, a constant regime is allowed for, as is volatility in the structural shocks only, policy shocks only, simultaneous volatility in structural and policy shocks, and independent volatility in structural and policy shocks.

Following this, statistical estimates are used to attach values to the model structural parameters. The discount factor (β) was fixed at 0.97, which translates into a long run annual average real interest rate of 3.09 per cent. The intertemporal elasticity of substitution of labour supply (ψ) is set at 1.30 to ensure that workers are willing to increase the number of hours worked in respond to temporary changes in wages. Debt elasticity with respect to interest rate risk premia (κ) is fixed at 1.45 per cent, which gives a default spread of 145 basis points as estimated by Allan Haung country risk premiums.[10] The share of foreign goods in consumption (α) and price elasticity of primary commodity exports (δ_e) are set to 0.24 and 0.14 respectively, based on a five-year average concentration and diversification indices from UNCTAD.[11]

The elasticty of substitution between home and foreign goods (ω) is set to 1.5, in that the markup for South Africa is comparable to the U.S. and euro area estimates, as established by Burger and Du Plessis (2013). Justiniano and Preston (2010) results are followed, and the underlisted parameters are fixed at 0.5. These are price indexation for home and foreign produced goods (δ_h, δ_f), price adjustment-cost for home and foreign produced goods (ϕ_h, ϕ_f) and degree of habit formation in consumption (λ) and elasticity of intertemporal substitution (τ).

It is assumed that the prior distributions of policy parameters switches, the

[10]This can be assessed from www.sjsu.edu/faculty/watkins/econ202/risk.htm.

[11] unctad.org/en/pages/statistics.aspx

priors for regime 1 and regime 2 are different as a result of money target and inflation targeting regimes. In particular, it is assumed that in regime 1, the prior responses are low for inflation and output, while in regime 2 the responses are high.[12] The responses to exchange rate depreciation and the macroeconomic condition index are high in regime 1 and low in regime 2. The prior choice for the regimes are in line with Ortiz and Sturzenegger (2007) and Peters (2016). According to them, the SARB targets the exchange rate prior to an inflation targeting regime while in post inflation targeting regime it does not target the exchange rate. Priors for the policy smoothing parameter (ρ_r) is set at 0.60 and policy innovations (σ^{er}) is set at 0.15. The priors for the transition matrice are set to 0.95 in each regime, based on Bianchi (2012), who states that regimes are persistent.

Further, it is assumed that the economy faces primary commodity export switches in innovations. In regime 1, the economy faces relatively low volatility in primary commodity innovations (σ^{ee}), with prior distributions of 0.37. While in regime 2, the economy faces high volatility with prior distribution of 0.87 in line with Nimark (2009). In addition, the prior distributions of the structural shocks processes follow beta distribution with values of 0.60. The priors for the variances in structural innovations follow a Weibull distribution with values of 0.18.

Following Liu et al. (2011) and Bjørnland et al. (2016), there is a departure from the normal practice of the direct usage of prior means and standard deviations, and this study uses quantiles distribution of the statistical estimates of the prior means to recover the hyperparameters with 90 percent probability interval of the distributions.[13]

[12]These formulation of the regime hypotheses are based on the evidence experienced in the South African economy or in other emerging economies instead of advanced economies.

[13]See, Gelman et al. (2014) for a detailed discussion and treatment of this approach. Similarly, see Gelman et al. (2014) pp.11 for the exposition on the credible intervals of the posterior densities, model checking and improvements.

4.5 Empirical Results

In this section, estimates of the Markov-switching DSGE model are reported. First, the model comparison results are presented to help select the best fit specification and also ensure that only the model that best fit the data is discussed. Following this, a detailed account of the parameter estimates and the smoothed transition probabilities is given. Thereafter, the robustness of the baseline model used is evaluated relative to alternative specifications. Finally, some light is shed on the generalised dynamic responses, variance and historical decompostions to determine various contributions of the shocks to the economy.

4.5.1 Model Comparison

In this subsection whether the data fit a particular model based on alternative specifications is investigated. This is done using the Akaike information criterion (AIC_c), Bayesian information criterion (BIC) and the log marginal data densities. Based on the log posterior densities reported in Table 4.1, the data is adjusted to obtain the AIC_c and BIC.

The model with volatility in structural shocks only has the lowest AIC_c and BIC scores indicating that this model is parsimonious for the South African economy. There is strong evidence in favour of the model with switches in volatility in the structural innovations only relative to policy only and a constant model, as shown in Table 4.1.

Next, the marginal likelihood, that is, the log-marginal data densities (log-MDD) is used to characterise the estimated DSGE model that best fits the data—the model with the largest marginal likelihood is considered as the best fit model, as reported in Table 4.1. The model with volatility in structural shocks only continues to outperform policy shocks volatility and the constant DSGE model. This result is similar to the finding of Liu et al. (2011) for the U.S. economy. To validate the results, a number of robustness tests were run to determine the appropriateness of the best fit model. In Table 4.4, it is seen that the model with volatility

Table 4.1: Statistics for model comparison

	Constant	VolPolSame	VolPolInd.	VolOnly	PolOnly
BIC	4025.18	39545.52	507480.22	3694.32	3921.72
AIC_c	3948.09	39459.89	507480.22	3584.26	3837.74
Log-posterior	-1930.75	-19656.20	-253618.59	-1738.04	-1866.62
Log-lik	-1801.89	-19618.26	-253617.24	-1679.07	-1792.15
Log-prior	-128.86	-37.94	-1.3533	-58.97	-74.47
Log-MDD(Laplace)	-2176.10	-19930	-253920.87	-1926.40	-2083.49

Note: Constant=structural shocks and policy parameters are time-invariant; VolPolSame=structural shocks and policy parameters switch simultanteous; VolPolInd=structural shocks and policy parameters switch independent; VolOnly=only volatility in the structural shocks are regime switching; PolOnly=policy parameters only are regime switching.

in structural shocks only continues to outperform all the alternative robustness check specifications.

This suggests that the regime-switching DSGE model with volatility in structural innovations only is preferred to either policy only switches or constant DSGE models. This, further, means that policy authorities should pay attention to variances emanating from structural shocks compared to shocks hitting the economy from policy innovations only. Following this, the results in relation to policy shocks only, combined and independent volatility in structural and policy shocks switches only are not discussed. The results are, however, provided for interested readers to make their own judgement in Appendix B 4.7.2.

4.5.2 Parameter Estimates

Estimates of the simulations are reported in Tables 4.2 and 4.3. First, the constant DSGE model is examined. This is followed by an examination of what is here considered as best fit model that is the volatility in structural innovations only

DSGE model.

Table 4.2 shows the posterior mode of the structural and innovation process parameters. The estimates of the constant DSGE model are reported in column

Table 4.2: Posterior mode of structural and shock process parameters

		Prior		**Posterior**			
Par.	Distr.	5%	95%	Constant	Volatility	5%	95%
λ	G	0.54	1.50	0.014	0.12	0.06	4.59
τ	G	0.54	1.50	1.93	1.17	0.06	4.59
α	G	0.54	1.50	0.12	0.09	0.06	4.59
ω	G	0.54	1.5	1.54	1.23	0.06	4.59
β	B	0.10	2.00	0.06	0.22	0.18	3.94
ϕ_h	G	0.58	1.00	0.008	0.10	0.25	1.58
ϕ_f	G	0.58	1.00	1.41	1.22	0.25	1.58
δ_h	G	0.54	1.50	1.92	0.21	0.06	4.59
δ_f	G	0.54	1.50	0.05	0.01	0.06	4.59
δ_e	G	0.54	1.50	0.003	0.012	0.06	4.59
ψ	G	0.54	1.50	1.65	1.18	0.06	4.59
κ	G	0.05	1.50	0.001	0.002	0.001	1.58
ρ_d	B	0.05	0.90	0.81	0.86	0.28	8.97
ρ_s	B	0.05	0.90	0.89	0.83	0.28	8.97
ρ_z	B	0.05	0.90	0.96	0.85	0.28	8.97
ρ_q	B	0.05	0.90	0.96	0.93	0.28	8.97
ρ_e	B	0.05	0.90	0.98	0.99	0.28	8.97
ρ_{fi}	B	0.05	0.90	0.19	0.21	0.28	8.97
ρ_{fy}	B	0.05	0.90	0.86	0.80	0.28	8.97
ρ_{fr}	B	0.05	0.90	0.45	0.61	0.28	8.97

Note: B=Beta distribution, G=Gamma distribution. See Gelman et al. (2014) pp.11 for exposition on why some of the posterior densities may be outside the Bayesian credible intervals.

5 of Table 4.2. It is revealed that the structural parameters are very similar

to Alpanda et al. (2010), who use a similar model to examine the responses of the SARB to exchange rate and other marcoeconomic variables. Although there are slight variations in the estimations as shown here, this may reflect the wider coverage of the data sample that includes the 1980s and the financial crisis in 2008 and beyond. The posterior mode for the inverse elasticity of labour supply (ψ) is 1.65, which is much higher than 1.45 for Alpanda et al. (2010) and 1.59 for Justiniano and Primiceri (2008). This may be due to the inclusion of the primary export sector explicitly in the model, coupled with a long period sample coverage. The estimated posterior mode for habit formation in consumption (λ) is 0.014, which is much lower than the 0.83 that was reported in Alpanda et al. (2010) for South Africa and the 0.81 that was reported in Justiniano and Primiceri (2008) for the US. Similarly, the lower impact of habit formation in consumption is slightly far from a median value of 0.14 that was reported by Liu and Mumtaz (2011) who use Markov-switching model for the U.K. economy.

Another feature of constant DSGE model estimates is that the shocks processes exhibit quite a high degree of persistence, except for foreign interest rate (ρ_{fr}) and foreign inflation (ρ_{fi}) shock processes, with an estimated posterior mode of 0.45 and 0.19, respectively. The estimated posterior mode for the share of foreign goods in domestic consumption (α) is 0.12. This suggests that trade policy pursued in the South African economy is less outward oriented. The estimated posterior mode for price adjustment cost for home (ϕ_h) and foreign produced goods ϕ_f are about 0.01 and 1.41, respectively. This may imply that home-produced goods adjust faster relative to price adjustment cost for foreign-produced goods. Contrary, the estimated posterior mode of price indexation for home-produced goods (δ_h) exhibit more stickness than foreign produced goods (δ_f). It can thus be concluded that the price adjustment cost for home-produced goods and the price indexation for foreign-produced goods have a long run pass-through effect as compared to price indexation for home-produced goods and price adjustment for foreign-produced goods.

Next, the estimated posterior modes of the policy parameters and the structural innovations for the Constant DSGE model are reported in column 5 of Table 4.3. The estimated policy parameters reveal that policy authorities respond significantly to inflation (γ_1) relative to output (γ_2) and exchange rate depreciation (γ_3). Another revealing feature is that inflation and output parameters of 1.26 and 0.63 are similar to Steinbach et al. (2009) values of 1.39 and 0.63 for inflation and output, respectively, although they did not take into account the exchange rate depreciation in their policy rule. The weights on inflation vis-a-vis output and exchange rate depreciation reflect the fact that the SARB is more responsive towards consumer price inflation variability relative to output volatility and exchange rate depreciation. It can also be concluded that policy authorities have a lower preference for exchange rate depreciation. The computed exchange rate posterior mode weight of 0.31 is slightly higher than the median value of 0.25 computed by Alpanda et al. (2010).

The estimated posterior mode for policy smoothing parameter (ρ_r) and its shock variances are 0.89 and 0.36 respectively. These are related to the estimates of Alpanda et al. (2010) of 0.92 and 0.24 for policy smoothing and its shock variances. The implication is that policy authorities prefer to stabilise policy rate smoothing to keep the inflation targeting regime credible. The variances of imported-cost inflation (σ_s), preference (σ_d) and foreign inflation (σ_{fi}) shocks are quite high, compared to technology (σ_z) and export (σ_e) shock variances as reported in Table 4.3. This may reflect the fact that the shocks hitting the South African economy are driven by import-cost inflation, preference and foreign inflation shock variances.

The volatility in structural innovations only DSGE model, herein the preferred model, is considered below. The results are displayed in column 6 of Tables 4.2 and 4.3. These results are very similar to the ones obtained in the constant DSGE model reported in column 5 of Tables 4.2 and 4.3. However, there are some important distinctions that need mention. Most of the estimated posterior modes

Table 4.3: Posterior mode of policy parameters and structural innovations

	Prior			**Posterior**			
Par.	Distr.	5%	95%	Constant	Volatility	5%	95%
ρ_r	B	0.60	0.90	0.89	0.98	0.48	3.97
γ_1	G	2.19	5.00	1.26	1.45	0.92	2.44
γ_2	G	0.30	3.00	0.63	0.71	0.69	1.01
γ_3	G	0.30	3.00	0.34	0.31	0.69	1.01
$vol_{tp,1}2$	B	0.95	0.99	-	0.42	0.43	0.96
$vol_{tp,2}1$	B	0.95	0.99	-	0.94	0.43	0.96
$\sigma_r(vol,1)$	W	0.18	1.00	0.36	0.04	0.13	1.54
$\sigma_r(vol,2)$	W	0.23	1.00	-	0.05	0.13	1.54
$\sigma_d(vol,1)$	W	0.18	1.00	0.76	0.95	0.13	1.54
$\sigma_d(vol,2)$	W	0.27	1.00	-	1.03	0.13	1.54
$\sigma_s(vol,1)$	W	0.37	1.00	2.77	1.29	0.13	1.54
$\sigma_s(vol,2)$	W	0.87	1.00	-	1.96	0.13	1.54
$\sigma_z(vol,1)$	W	0.18	1.00	0.35	1.81	0.13	1.54
$\sigma_z(vol,2)$	W	0.23	1.00	-	0.87	0.13	1.54
$\sigma_q(vol,1)$	W	0.37	1.00	0.33	0.68	0.13	1.54
$\sigma_q(vol,2)$	W	0.87	1.00	-	0.67	0.13	1.54
$\sigma_e(vol,1)$	W	0.37	1.00	0.54	1.36	0.13	1.54
$\sigma_e(vol,2)$	W	0.87	1.00	-	1.62	0.13	1.54
$\sigma_{fi}(vol,1)$	W	0.18	1.00	0.78	1.21	0.13	1.54
$\sigma_{fi}(vol,2)$	W	0.23	1.00	-	1.43	0.13	1.54
$\sigma_{fy}(vol,1)$	W	0.18	1.00	0.57	0.68	0.13	1.54
$\sigma_{fy}(vol,2)$	W	0.23	1.00	-	0.18	0.13	1.54
$\sigma_{fr}(vol,1)$	W	0.18	1.00	0.17	0.20	0.13	1.54
$\sigma_{fr}(vol,2)$	W	0.23	1.00	-	0.18	0.13	1.54

Note: B=beta distribution, G=Gamma distribution and W=Weibull distributin. See Gelman et al. (2014) pp.11 for exposition on why some of the posterior densities may be outside the Bayesian credible intervals.

of the structural and shock process parameters decline marginally in magnitude, with the exception of export shock, foreign inflation, foreign interest rate and preference shock processes. This may show how critical these variables have become in the design of monetary policy.

With respect to the estimated posterior mode of inverse elasticity of labour supply (ψ) is 1.18 compared to 1.65 in the constant model in Table 4.2. This implies that workers have to use about 0.85 more hours of their time to work when volatility increase in the economy is compared to 0.61 in the constant model. Thus, an increase in volatility of the structural innovations have negative effects on the welfare of workers in this context.

The posterior mode of the price elasticity of exports demand (δ_e) value of 0.012 suggests that at present South Africa's gold export demand is price inelastic. However, when volatility in the structural innovations are accounted for, the value increases from 0.003 to 0.012, respresenting about a 300 per cent increase. This suggests that changes in world prices of primary commodity exports contribute to major shifts in macroeconomic outcomes in emerging economies that depend on primary commodity exports. Clearly, the movements in the commodity exports price presents a challenge to the economy because of its larger effect on fiscal policy and the balance of payments.

Similarly, the commodity export shock process ρ_e of 0.99 is quite high. Since the shock process parameter is a long-lived one, it is most likely that the cost of policy stabilisation may exceed gains from policy smoothing ρ_r of 0.98. In the light of this, there is likely to be a little scope for successful implementation of policy stabilisation. In regime 2 export shock variance ($\sigma_e(vol, 2)$) is 1.62, this is much higher relative to regime 1 export shock variance of 1.36, as shown in Table 4.3. This evidence suggests that the primary commodity export sector may have an important role to play in the design of monetary policy in emerging economies. This study reveals that one of the main drivers of shocks variances hitting the economy is the primary commoditiy export shock. What is more, is that it can be deduced that the constant DSGE model may pick up some of the shock variances emanating from primary commodity export shocks leading to bias conclusions.

Regarding the policy parameters of inflation, output, and exchange rate depreciation, the values are slightly higher compared to the constant DSGE model estimates, except the exchange rate. The weights are 1.45, 0.71 and 0.31 for inflation (γ_1), output (γ_2) and exchange rate (γ_3), respectively. It is proposed here that when volatility increases in the structural innovations, policy authority pays more attention to inflation and output relative to the exchange rate. This is to ensure that policy authority does not deviate from its policy objectives of stable inflation and output growth.

The estimated posterior mode of the interest rate smoothing (ρ_r) is 0.98, slightly higher than what has been observed in the South African economy. This suggests that when the economy experiences high volatility in structural shocks, policy authorities either engage in smoothing the interest rate to keep the financial markets sound instead of either explicitly targeting the exchange rate or intervening in the activity of the foreign exchange market. It is thus suggested that when volatility increases, policy authorities are willing to combine price stability with financial stability (see also Clarida et al. (1999) and Woodford (2003a) for the reasons why a central bank may smoothing the interest rates). However, the variances of the policy shock $\sigma_r(vol, 1)$ reduced from 0.36 in the constant DSGE to 0.04 in regime 1 and 0.05 in regime 2. This implies that an increase in volatility makes monetary policy less effective. The conclusion here is that the effects of policy shocks is clearly weaker when the economy experiences a rise in volatility of the structural shocks. The evidence given as shown above, there is little support for this view in the literature discussed earlier that monetary policy is important in influencing the level of aggregate variables in the economy.

Finally, the estimated posterior mode variances for the transition probabilities of regime 2 is quite high. In regime 2 ($vol_{tp,2}$), that is, the high volatility state has estimated posterior mode of 0.95 is substantially larger compared to regime

1 ($vol_{tp,1}$) variance of 0.42. This shows that the responses of policy authorities to inflation and output are high in regime 2 compared to regime 1, which also suggests that policy authority prefers to remain longer in the inflation targeting regime compared to the monetary aggregates regime.

4.5.3 Smoothed Transition Probabilities

The top panel of Figure 4.2 in Appendix B 4.7.2 shows the smoothed transition probabilities for high volatility state in regime 2. Thus two major high volatility states in the South African economy are identified for the periods 1981 to 1985 and 2008 to 2010. From 1981 to 1985, the South African economy experienced the longest period ever of high macroeconomic volatility. The high volatility regime coincided with gold price shock, poor sovereign risk rating, trade and financial sanctions that adversely affected the economy over the period 1981 and 1985. Similarly, the high volatility regime is consistent with the SARB estimates of downswing business cycle phases that lasted about 40 months between 1981 and 1986. The second major shift was in 2008, when the global economy experienced the financial crisis. This suggests that the South African economy is financially integrated into the global economy, therefore, major global events are likely to affect the domestic economy.

A critical observation of the top panel of Figure 4.2 shows that there are many short periods of high macroeconomic volatility. These short period volatilities coincided with domestic events in the economy, such as large capital outflows towards the run up to the 1994 election and over the period 2001 to 2002, when the economy witnessed an exchange rate depreciation of over 30 per cent.

The bottom panel of Figure 4.2 shows the low monetary policy response state in regime 2 on a macroeconomic condition index. Thus policy switched from a high monetary policy regime to a low monetary policy regime from 1985 until 2003. This suggests that the actual conduct of monetary aggregates regime ended in 2003, according to the plot in the bottom panel of Figure 4.2. Besides, this implies that the effect of monetary policy responses to macroeconomic condition index is low, beginning 2003. Following this, the policy authority switched from responding more towards a marcoeconomic condition index, such as the exchange rate in 2003, to responding more to inflation and output stability after the adoption of an inflation targetiing regime.

4.5.4 Robustness Check

The aim of this subsection is to evaluate the robustness of the baseline model used here in relation to two alternative specifications as reported in Figure 4.4, for the baseline model might not be parsimonious as described by the data. First, gold exports are replaced with merchandise exports, in that they capture heterogenous clusters of primary commodity exports. Secondly, the baseline model is restricted similar to Justiniano and Preston (2010), in case the primary commodity export shock biases these baseline results.

Table 4.4: Robustness check: Statistics for model comparison

	BIC	AIC_c	Log-MDD	Log-posterior	Log-like	Log-prior
MEX	6416.20	6326.37	-3398.25	-3098.98	-3023.97	-75.01
REM	3826.86	3740.65	-2010.87	-1814.23	-1721.64	-92.59
Vol	3694.32	3584.26	-1926.40	-1738.04	-1679.07	-58.97

Note: MEX=merchandise exports and assume the structural shocks are regime switching. REM=restricted model, that is, the original model of Justiniano and Preston (2010) and assume the structural shocks are regime switching, Vol=volatility only in the structural shocks are regime switching.

The two alternative specifications reveal that the model with volatility in structural shocks only fit the data better. The models' selection criterion is compared with the baseline model, as reported in Table 4.4. The three criteria, namely AIC_c, BIC and log-MDD, show that the chosen baseline model outperforms the other two specifications. Most of the parameter estimates of the two alternative specifications are displayed in Tables 4.7 and 4.8 in Appendix B 4.7.2. These are very similar to these baseline estimates with few variations in the estimates although there are huge differences in the the transition probabilities and shock variances.

4.5.5 Evolution of Macroeconomic Outcomes in the South African Economy

The generalised dynamic responses, variance and historical decompositions of the volatility in structural shocks DSGE model are used in this section to evaluate the performance of the South African economy. It is only observed domestic variables relevant to this study that are examined to keep the discussion brief.

4.5.5.1 Generalised Dynamic Responses

To characterise the macroeconomic outcomes of the South African economy, the generalised dynamic responses are investigated in this section. A one standard deviation of a policy shock, as reported in the first block of Figure 4.3, generates about 0.2 per cent decline in real consumption and this leads to about 0.1 per cent decline in output growth. As output growth declines, it slows down increases in consumer price inflation by about 1.5 per cent and gradually decay within 3 quarters. This transmission is consistent with inflation targeting principles in that once policy authority adjusts the policy rate, investments decline and this leads to a decline in output growth and slows inflationary pressures. It is also found that a policy shock transmits about 2 per cent to exchange rate appreciation and this results in about 0.4 per cent fall in import cost inflation.

Regarding export shock reported in the last block of Figure 4.3, a one standard deviation of export shock results in about 0.007 per cent reduction in policy rate. This transmits approximately a 1.8 per cent increase in gold export, which translates to about a 0.03 per cent output growth. This means that a reduction in policy rate serves as an incentive for a lower cost of gold extraction and raises gold revenues, which in turn boost output growth.

A positive risk premium shock, as shown in the first block of Figure 4.4, is followed by more than a 5 per cent to exchange rate depreciation. This translates into an about 1 per cent increase in import-cost inflation. The effect on import-cost inflation gradually decays within 12 quarters, which generates an about 0.2 per cent slowdown in consumer price inflation. This improves on the terms of trade by about 2.5 per cent and also provides a marginal increase in output growth. With respect to import-cost inflation as shown in the last block of Figure 4.4, a one standard deviation leads to an about 0.1 per cent increase in policy rate. This further generates an about 2 per cent decline in real household consumption and leads to an about 0.2 per cent reduction in output growth. This follows a consumer price inflation increase of about 4 per cent.

It is found that a one standard deviation to a preference shock in the first block of Figure 4.5 generates an about 2 per cent increase in real household consumption, which stabilises within 12 quarters. This increases output growth by about 1 per cent and leads to a 2 per cent increase in consumer price inflation. The preference shock also leads to exchange rate appreciation by about 2 per cent, which generates a decline in gold exports by about 0.15 per cent. A technology shock in the last block of Figure 4.5 transmits a positive response to gold exports. It has, however, a depreciating effect on consumer price inflation. The responses to real consumption and nominal effective exchange rate depreciation are lower.

It is worth mentioning that import-cost inflation, risk premia and export shocks have a larger impact on macroeconomic movements compared to monetary policy shock.

4.5.5.2 Counterfactual Dynamic Responses

Because this work is interested in the responses of each regime, regime 1 and regime 2 are compared with respect to policy, exports, import-cost inflation and risk premia shocks to isolate the effects of the dynamics of each regime.

In the first and last blocks of Figure 4.6, policy responses in regime 1 and regime 2 are compared. The policy responses in regime 2 is much larger relative to the responses in regime 1 by about 0.3 per cent for inflation and output. This implies that in regime 2 policy authority is much more concerned with inflation and output stability relative to regime 1, and this is also supported by the estimates in Table 4.3. Similarly, the first and last blocks of Figure 4.7 show the responses to export shock regimes. In regime 2, export shocks have relatively larger effect on inflation and output, exchange rate and gold exports compared to policy rate, while in regime 1 export shocks have larger effects on policy rate. This suggests that in regime 2—an inflation targeting regime—minimal shocks from export shocks may have helped the conduct of monetary policy relative to regime 1, which is a monetary aggregates regime.

Figure 4.8 shows the import-cost inflation regimes. Regime 1 shows higher pass-through effects of import cost inflation relative to regime 2. This suggests that the exchange rate pass-through to import prices then to consumer price inflation has been well managed in an inflation targeting regime as compared to a monetary targeting regime. Important evidence is given in the risk premia regimes as reported in Figure 4.9. This shows that the effect of risk premia shocks and its volatility remain relatively the same in inflation targeting and monetary aggregates regimes. This suggests that the two regimes are less effective in helping to reduce risk premia shocks in the economy.

4.5.5.3 Variance Decompositions

To understand the relative importance of each variable to another at each forecast horizon and thus the extent of their interaction over a particular forecast horizon, the variance decompositions are evaluated and the estimates in Figure 4.10 through to Figure 4.12 are reported upon.

In the left panel of Figure 4.10, the variance decomposition of the policy rate shows that technology and import-cost shocks are the main contributors to policy rate volatility. In the long run, the size of import-cost inflation is larger relative to a technology shock. One striking finding is that monetary policy shock variances have barely no impact on policy rate, as reported in the left panel of Figure 4.10. The variance decomposition of consumer price inflation in the right panel of Figure 4.10 reveals that technology and import cost inflation shocks drive consumer price inflation volatility, but policy shock remains small in consumer price inflation volatility. This result is consistent with the real business cycle thesis in which technology shock is the main driver of volatility in an economy. This suggests that in an inflation targeting regime, policy authority should pay attention to technology and import-cost inflation because of their larger effects on the inflation and policy rate.

Regarding the variance decomposition of output gap in the left panel of Figure 4.11, preference shock is the main driver of output gap volatility. Although import-cost inflation, risk premia and technology shocks have a slight effect on output gap volatility, monetary policy shock variances do not affect output gap. A similar pattern is exhibited in the real consumption in the right panel of Figure 4.11. However, import-cost inflation contributes relatively larger volatility to real consumption in the long run compare to output gap growth.

Gold exports in the left panel of Figure 4.12, show that monetary policy, risk premia and foreign shocks do not have significant impact on gold exports volatility. Instead, export, import-cost inflation and technology shocks are the main contributors to gold exports variability. With regards to exchange rate variable in the right panel of Figure 4.12, the main contributor to exchange rate variability is the risk premia shock. Moreover, changes in policy shock has smaller effect on exchange rate depreciation relative to risk premia shock. This implies that on average, the short-term interest rate in South Africa is relatively higher as compared to foreign investor country and thus generates excess returns for investors.

In conclusion, the results of the variance decompositions suggest that the major drivers of macroeconomic volatility in the South African economy are import-cost inflation, technology changes, commodity exports and preference changes. These findings seem to be consistent with South Africa, an emerging economy with a volatile currency that experiences volatile portfolio flows and went through financial market liberalisation, and is thus susceptible to adverse exchange rate shocks. Moreover, the majority of its exports are primary commodities and a large component of its imports are usually manufactured goods. Further, the South African currency was one of the most important currencies of emerging economies over the period 1998 to 2013 and usually has a trade ranking between the top 10 and top 20 in the currencies distribution of global foreign exchange market turnover.[14]

4.5.5.4 Historical Decompositions

The historical decompositions are analysed to help identify the role played by the shocks in the movements of domestic observed variables.

The left panel of Figure 4.13 shows a different contribution of shocks to movements in policy rate. From 1982 to 1990, import cost inflation and export shocks subtracted from the policy rate. This meant that the economy was saddled with structural bottlenecks, such as a high desire for imported goods and weak export promotion relative to demand management policies. In 2000 and 2003, however, it became modest, for this trend was reversed during the global financial crisis until 2016, contributing positively to policy rate movements. In the mid 1990s to 2016, export and preference shocks made a positive contribution to upward movements in policy rate. Risk premia and technology shocks accounted for a positive contribution to policy rate movements in the 1980s until 1994. But this trend was

[14] See Bank for International Settlement preliminary global results on the Triennal Central Bank Survey Foreign exchange turnover in April 2014. South Africa also has the most developed financial markets in sub-Saharan African and a higher financial development index that is of higher ranking relative to even some developed and emerging economies such as Italy, Poland, Brazil, Chile and Russia, among others. This can be found in the World Economic Forum Financial Development Ranking Report 2012.

reversed from the beginning of 1999 to 2016, as risk premia and technology shock made a negative contribution to the policy rate. This suggests that an increase in technology and capital inflows lead to output growth.

Regarding consumer price inflation reported in the right panel of Figure 4.13, the main driver of movements in consumer price inflation is import-cost inflation shock. In the mid 1980s, import-cost inflation shock showed a negative effect on consumer price inflation. However, from 1986 to 2008, it showed persistent upswings and downswings in the movements of consumer price inflation. After the global financial crisis of 2008, the swings continued but with less pass-through to consumer price inflation. This may suggest that lower import cost inflation to consumer price inflation can in part be attributed to trade integration of the South African economy. However, policy shock has a neglible effect on consumer price inflation.

Prior to 1999, import cost inflation and risk premia shocks positively contributed to output growth movements but remained modest between 1999 to 2005, as reported in the left panel of Figure 4.14. Afterwards this trend is reversed, where import cost inflation and risk premia shock contribute negative to output growth. Similarly, preference shocks contributed negative to output growth beginning in 1991 until 1997. From 2008 to 2016, technology and preference shocks contributed positive to output growth, whereas risk premia and import cost inflation substracted from output. These findings suggest that downward movements in import-cost inflation and risk premia and upward movements in technology and preference changes can stimulate the economy, even to holding policy rate constant. A similar trend is observed in the real household consumption, as reported in the right panel of Figure 4.14. However, import-cost inflation has a larger effect on real household consumption.

With respect to gold exports shown in the left panel of Figure 4.15, import-cost inflation and technology shocks contributed negatively to gold exports movements from 1981 to 2008. Beginning in 2008, import-cost and technology shocks had a positive effect on gold exports movements. Likewise, risk premia, exports and preference shocks contribute positively to gold export growth from 1998 to 2010, while from 2003 risk premia and export shocks made a negative contribution to gold exports movements. The right panel of Figure 4.15 reports the movements in exchange rate depreciation. This shows that from 2008 until 2016, import-cost inflation, export, and risk premia subtracted from exchange rate depreciation, whereas technology shock positively impacted on real exchange rate.

To sum up, it is found that import cost inflation, risk premia, technology, preference, and export shocks are the main drivers in the movements of macroeconomic variables in the South African economy. Therefore, it is proposed that the policy authority should endeavour to identify the sources that contribute to macroeconomic fluctuations. Once the sources are identified, then policy authority is advised to understand the effects of the underlying factors more broadly instead of paying attention to changes in the monetary policy rule only.

4.6 Conclusion

In macroeconomic modeling, the importance of establishing the sources that account for economic fluctuations has always been underscored. In this chapter, therefore, empirical evidence of some of the likely sources of macroeconomic volatility is provided. The primary commodity export sector shock is thus allowed to follow a regime switching process and carry out Bayesian inference in a Markov-switching dynamic stochastic general equilibriun model. The present findings suggest that constant dynamic stochastic general equilibrium model results are very similar to the evidence in the literature with slight variations. Whereas in the volatility in structural innovations only model, some of the estimated posterior modes of the structural and shock processes fall marginally, exports, import-cost inflation, technology and preference shock persistence are high. This indicates that these shock processes have relatively long-lived effects on macroeconomic outcomes in emerging economies.

In addition, the estimated policy parameters reveal that policy authority responses to inflation is significant relative to output and exchange rate depreciation. Two major high macroeconomic volatilities are identified in the transition probabilities that coincide with the movements in the observed variables and the business cycle phases in the South African economy. Another finding shows that a monetary policy shock decreases the output gap, but has a negligible effect on consumer price inflation. In historical and variance decompositions, import-cost inflation shock, preference shock, technology shock, risk premia and export shocks are the main drivers of economic performance in the domestic economy. In short, the model with the primary commodity export sector coupled with volatility in structural shocks better explain macroeconomic dynamics in an emerging economy as compared to alternative experiements.

Of course this study is not conclusive, the transition probabilities of the switching parameters are time-invariant, that is, subject to critique. This, therefore, requires that the switching parameters are endogenised. However, due to the computational complexity of the Markov-switching dynamic stochastic general equilibrium, a reduced-form Markov-switching vector autogression model is employed in the next chapter to shed light on how the transition probabilities parameters vary over time, although in a different context. Moreover, future research along these lines is needed to understand how these models work and interact to shape monetary policy conduct in the South African economy and similar emerging economies.

4.7 Appendix B: Chapter 4

4.7.1 Model Equations

Table 4.5: Rest of model equations fitted to data

Description	Equation
Terms of trade	$s_t = s_{t-1} - \pi_t^h + \pi_t^f$
Exchange rate depreciation	$\Delta e_t = q_t - q_{t-1} + \pi_t - \pi_t^{fi}$
CPI inflation	$\pi_t = (1-\alpha)\pi_t^h + \alpha\pi_t^f$
Net foreign assets	$nfa_t = \frac{1}{\beta} nfa_{t-1} - \alpha(q_t + \alpha s_t) + y_t - c_t$
Shock processes	
Export shock	$ze_t = \rho_e ze_{t-1} + \sigma^{ee}$
Preference shock	$zd_t = \rho_d zd_{t-1} + \sigma^{ed}$
Import cost shock	$zs_t = \rho_e zs_{t-1} + \sigma^{es}$
Technology shock	$zp_t = \rho_z zp_{t-1} + \sigma^{ep}$
Risk premia shock	$zq_t = \rho_q zq_{t-1} + \sigma^{eq}$
Foreign inflation shock	$\pi_t^{fi} = \rho_{fi}\pi_{t-1}^{fi} + \sigma^{efi}$
Foreign output shock	$y_t^{fy} = \rho_{fy} y_{t-1}^{fy} + \sigma^{efy}$
Foreign interest rate shock	$r_t^{fr} = \rho_{fr} r_{t-1}^{fr} + \sigma^{efr}$

Table 4.6: Parameters and variables description

Parameter	Description	Variable	Description
δ_e	Price elasticity of export demand	xe_t	Export demand
α	Share of foreign goods in consumption	y_t^{fy}	Foreign output gap
ω	Elasticity of sub betw. home and foreign goods	pw	Relative price of exports
δ_h	Price index for home-produced goods	π_t	CPI inflation
δ_f	Price index for foreign-produced goods	s_t	Terms of trade
β	Subjective discount factor	c_t	Final household consumption
ϕ_h	Price adjustment cost for home-produced good	r_t	Policy rate
ϕ_f	Price adjustment cost for foreign-produced good	y_t	Output gap
ψ	Inverse elasticity of labour supply	q_t	Real exhange rate
κ	Debt elast. w.r.t. interest rate risk premia	e_t	Nominal exchange rate
τ	elasticity of intertemporal substitution	π^f	Import cost inflation
γ_1	Weight on inflation param.	π^h	Domestic inflation
γ_2	Weight on output param.	π^{fi}	Foreign inflation
γ_3	Weight on changes in exchange rate	nfa_t	Net foreign assets
ρ_r	Policy rate smoothing param.	ze_t	Export demand shock process
ρ_e	Persistence param. for export shock	zd_t	Preference shock process
ρ_d	Persistence param. for preference shock	zp_t	Technology shock process
ρ_s	Persistence param. for imported inflation shock	zs_t	Import-cost shock process
ρ_z	Persistence param. for technology shock		
ρ_q	Persistence param. for risk premia shock	zq_t	Risk premia shock process
ρ_{fi}	Persistence param. for foreign inflation shock	σ^{er}	Policy shock
ρ_{fy}	Persistence param. for foreign output shock	σ^{ed}	Preference shock
ρ_{fr}	Persistence param. for foreign interest rate shock	σ^{ep}	technology shock
σ^{ee}	Standard deviation of export shock	σ^{es}	Import cost shock
σ^{ed}	Standard deviation of preference shock	σ^{eq}	Risk premium shock
σ^{es}	Standard deviation of import-cost shock	σ^{ee}	export demand shock
σ^{ep}	Standard deviation of technology shock	σ^{efi}	foreign inflation shock
σ^{eq}	Standard deviation of risk premia shock	σ^{efy}	foreign output shock
σ^{efi}	Standard deviation of foreign inflation shock	σ^{efr}	foreign interest rate shock
σ^{efy}	Standard deviation of foreign output shock	λ	Habit formation
σ^{efr}	Standard deviation of foreign interest rate	r_t^{fr}	Foreign interest rate

4.7.2 Estimation Results

Table 4.7: Robustness check: Posterior mode of structural and shock processes

	Prior			**Posterior Mode**						
Par.	Distr.	5%	95%	VolPolSame	VolPolInd	Polonly	MEX	REM	5%	95%
λ	G	0.54	1.50	0.31	0.49	0.04	0.32	0.62	0.06	4.59
τ	G	0.54	1.50	0.11	0.49	1.05	0.67	1.93	0.06	4.59
α	G	0.54	1.50	0.12	0.41	0.09	0.14	0.05	0.06	4.59
ω	G	0.54	1.50	1.04	0.51	1.86	0.97	1.64	0.06	4.59
β	B	0.10	2.00	0.09	0.10	0.14	0.05	0.22	0.18	3.94
ϕ_h	G	0.58	1.00	0.003	0.003	0.013	0.002	0.001	0.25	1.58
ϕ_f	G	0.58	1.00	0.84	0.48	0.83	0.61	0.98	0.25	1.58
δ_h	G	0.54	1.50	0.19	0.36	0.11	0.29	0.22	0.06	4.59
δ_f	G	0.54	1.50	0.24	0.39	0.003	0.01	0.02	0.06	4.59
δ_e	G	0.54	1.50	0.05	0.12	0.004	005	-	0.06	4.59
ψ	G	0.54	1.50	0.22	0.36	0.49	1.12	1.19	0.06	4.59
κ	G	0.05	1.50	0.11	0.43	0.002	0.13	0.001	0.001	1.58
ρ_d	B	0.05	0.90	0.81	0.78	0.89	0.84	0.88	0.28	8.97
ρ_s	B	0.05	0.90	0.71	0.83	0.85	0.87	0.47	0.28	8.97
ρ_z	B	0.05	0.90	0.73	0.74	0.87	0.93	0.90	0.28	8.97
ρ_q	B	0.05	0.90	0.99	0.89	0.91	0.97	0.93	0.28	8.97
ρ_e	B	0.05	0.90	0.99	0.97	0.99	0.34	-	0.28	8.97
ρ_{fi}	B	0.05	0.90	0.46	0.58	0.25	0.58	0.61	0.28	8.97
ρ_{fy}	B	0.05	0.90	0.47	0.59	0.89	0.99	0.62	0.28	8.97
ρ_{fr}	B	0.05	0.90	0.42	0.51	0.27	0.43	0.98	0.28	8.97

B=Beta distribution, G=Gamma distribution, See Gelman et al. (2014) pp.11 for exposition on why some of the posterior densities are outside the Bayesian credible intervals. VolPolSame=structural shocks and policy parameters are simultanteous regime switching. VolPolInd=structural shocks and policy parameters switch independent. PolOnly=policy parameters and shocks only are regime switching, MEX=merchandise exports with regime switching. REM=restricted model that is the original model of Justiniano and Preston (2010).

Table 4.8: Robustness check: Posterior mode of policy parameters and structural innovations

	Prior			**Posterior Mode**						
Par.	Distr.	5%	95%	VolPolSame	VolPolInd	PolOnly	MEX	REM	5%	95%
ρ_r	B	0.6	0.90	0.40	0.52	0.99	0.68	0.94	3.47	8.97
$\gamma_1(vol,1)$	G	2.19	5.00	1.64	1.92	2.16	3.15	5.94	0.92	2.44
$\gamma_1(vol,2)$	G	0.77	5.00	0.39	0.34	2.05	-	-	0.92	2.44
$\gamma_2(vol,1)$	G	0.30	3.00	0.14	0.27	0.16	0.31	0.70	0.69	1.01
$\gamma_2(vol,2)$	G	0.17	3.00	0.25	0.15	0.00	-	-	0.69	1.01
$\gamma_3(vol,1)$	G	0.30	3.00	0.20	0.26	0.26	0.002	0.00	0.69	1.01
$\gamma_3(vol,2)$	G	0.17	3.00	0.25	0.15	0.00	-	-	0.69	1.01
$vol_{tp,1}2$	B	0.95	0.99	0.71	0.949	-	0.95	0.15	0.43	0.96
$vol_{tp,2}1$	B	0.95	0.99	0.75	0.949	-	0.20	0.04	0.43	0.96
$coefl_{tp,1}2$	B	0.95	0.99	-	0.948	0.00	-	-	0.43	0.96
$coefl_{tp,2}1$	B	0.95	0.99	-	0.949	0.00	-		0.43	0.96
$\sigma_r(vol,1)$	W	0.18	1.00	0.12	0.14	0.03	0.77	0.37	0.13	1.54
$\sigma_r(vol,2)$	W	0.23	1.00	0.21	0.23	-	0.77	1.05	0.13	1.54
$\sigma_d(vol,1)$	W	0.18	1.00	0.14	0.17	0.70	0.30	0.001	0.13	1.54
$\sigma_d(vol,2)$	W	0.27	1.00	0.33	0.27	-	0.93	1.16	0.13	1.54
$\sigma_s(vol,1)$	W	0.37	1.00	0.21	0.31	2.71	0.001	6.32	0.13	1.54
$\sigma_s(vol,2)$	W	0.87	1.00	0.97	0.74	-	8.57	9.36	0.13	1.54
$\sigma_z(vol,1)$	W	0.18	1.00	0.14	0.18	1.52	1.81	0.14	0.13	1.54
$\sigma_z(vol,2)$	W	0.23	1.00	0.35	0.30	-	0.37	0.48	0.13	1.54
$\sigma_q(vol,1)$	W	0.37	1.00	0.22	0.32	1.18	0.003	0.003	0.13	1.54
$\sigma_q(vol,2)$	W	0.87	1.00	0.66	0.85	-	3.94	1.04	0.13	1.54
$\sigma_e(vol,1)$	W	0.37	1.00	0.22	0.28	1.90	0.006	-	0.13	1.54
$\sigma_e(vol,2)$	W	0.87	1.00	0.65	1.20	-	5.47	-	0.13	1.54
$\sigma_{fi}(vol,1)$	W	0.18	1.00	0.14	0.16	1.78	0.42	37.38	0.13	1.54
$\sigma_{fi}(vol,2)$	W	0.23	1.00	0.25	0.20	-	1.13	0.66	0.13	1.54
$\sigma_{fy}(vol,1)$	W	0.18	1.00	0.13	0.15	0.72	0.09	0.38	0.13	1.54
$\sigma_{fy}(vol,2)$	W	0.23	1.00	0.16	0.20	-	0.46	0.70	0.13	1.54
$\sigma_{fr}(vol,1)$	W	0.18	1.00	0.13	0.15	0.18	1.04	0.07	0.13	1.54
$\sigma_{fr}(vol,2)$	W	0.23	1.00	0.16	0.21	-	0.18	0.14	0.13	1.54

MEX=merchandise exports with regime switches; REM= the original model of Justiniano and Preston (2010); VolPolSame=structural shocks and policy parameters switches; VolPolInd=structural shocks and policy parameters switch independent. PolOnly=policy parameters switches only.

Figure 4.2: Smoothed transition probabilities

Note: Top panel is high volatility in regime 2 and bottom panel is low monetary policy response in regime 2

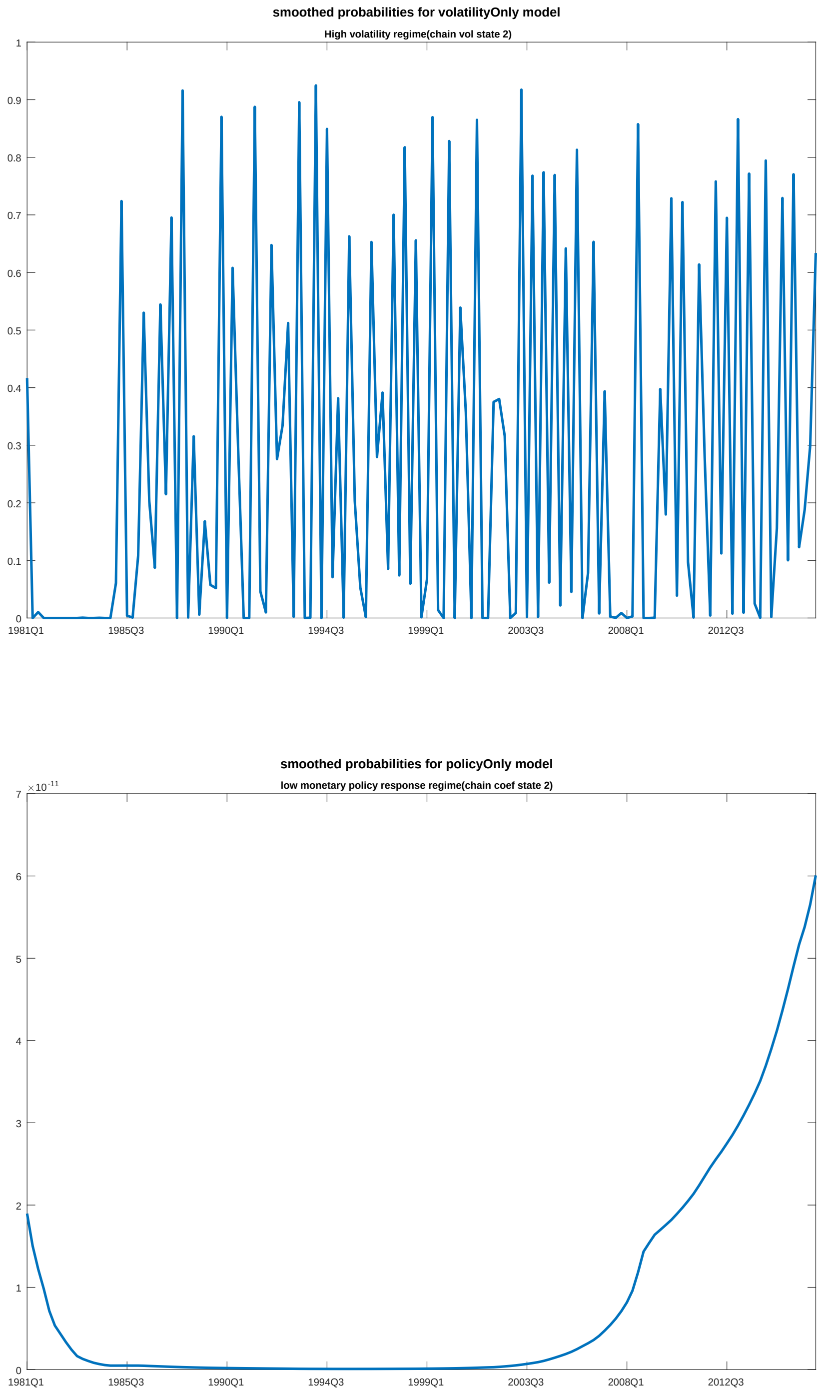


Figure 4.3: Dynamic responses to policy and export shocks

Note: First block is a policy shock and last block is an export shock

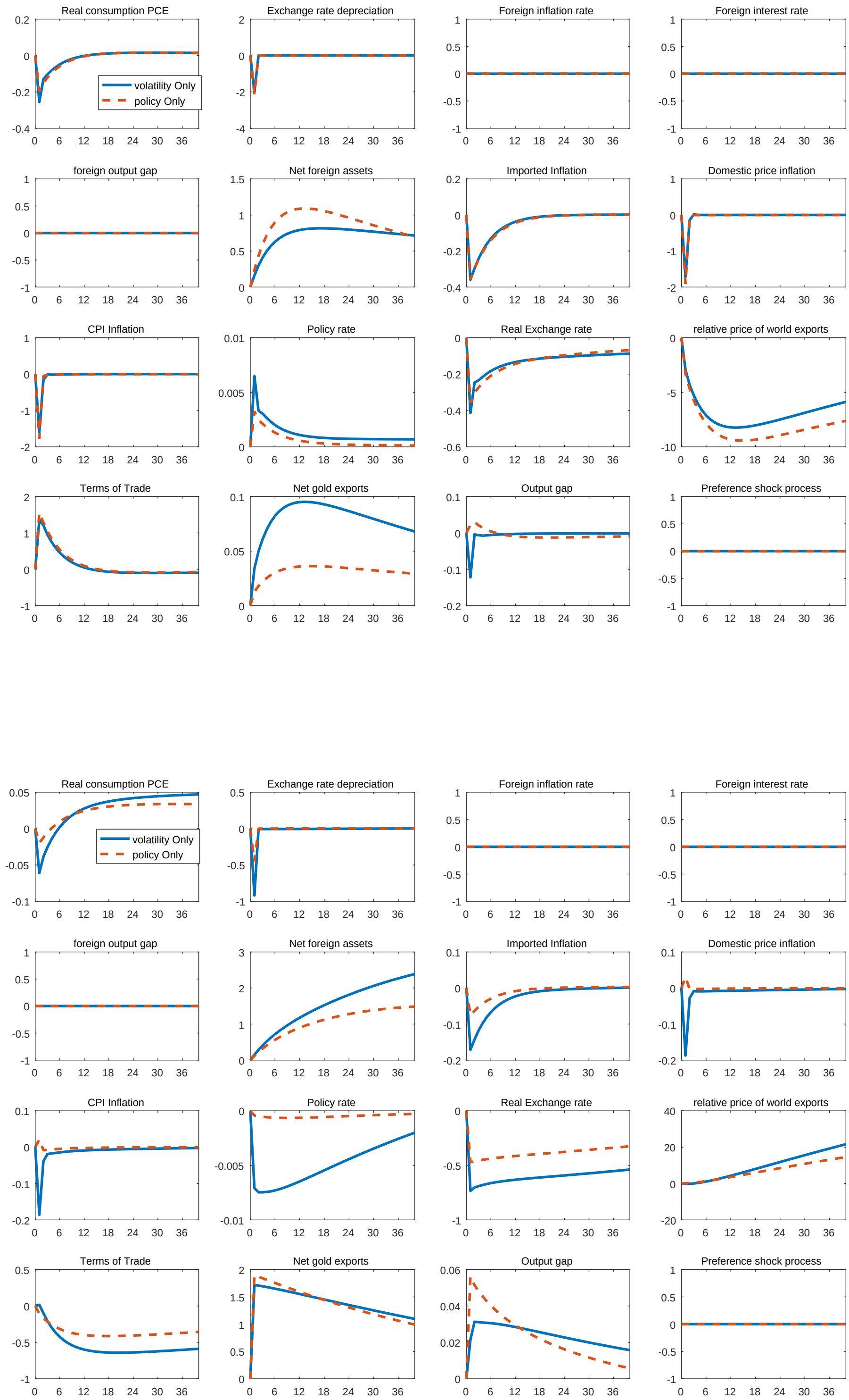


Figure 4.4: Dynamic responses to risk premia and import-cost inflation shocks

Note: First block is a risk premia shock and last block is an import cost inflation shock

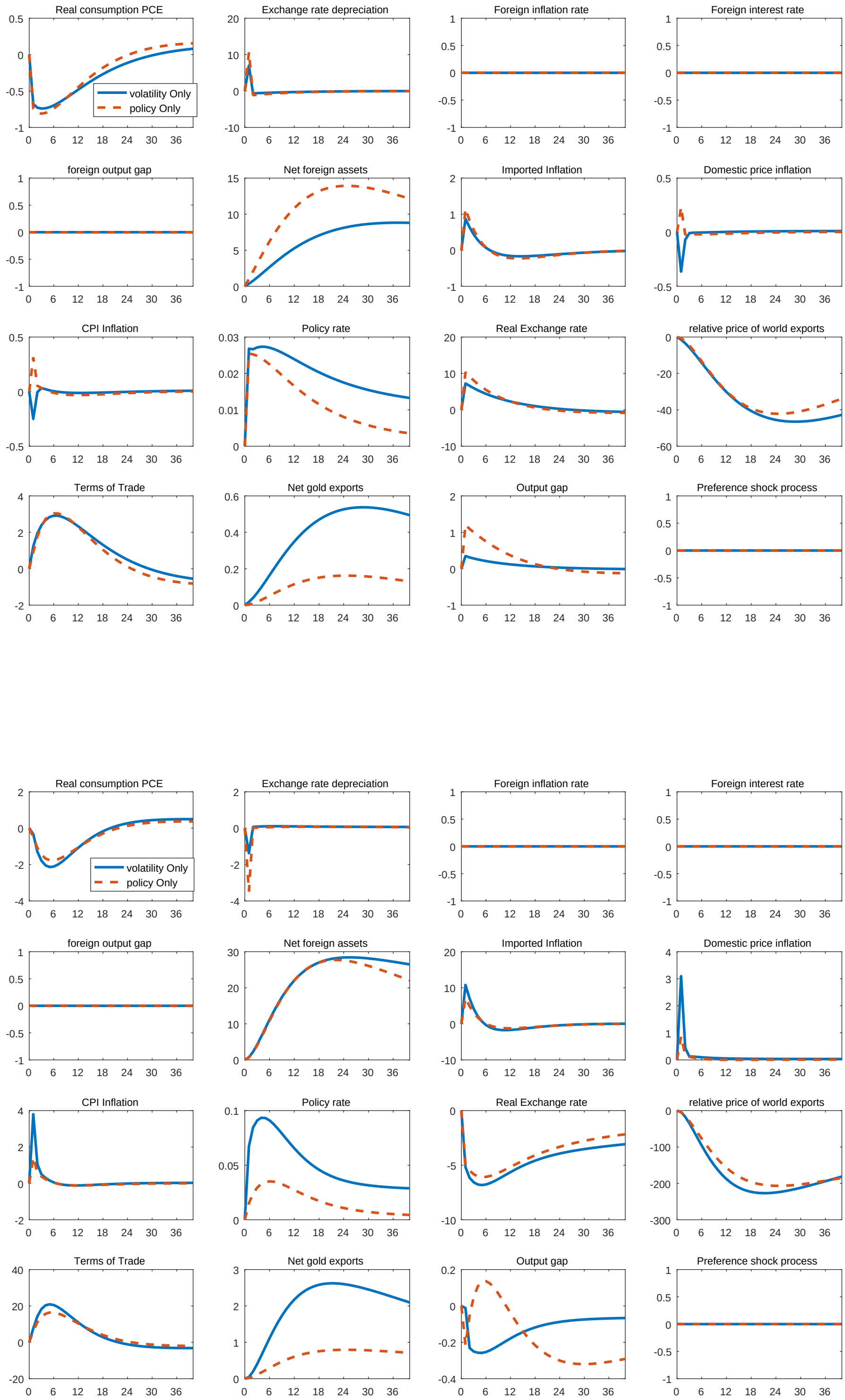


Figure 4.5: Dynamic responses to preference and technology shock

Note: First block is a preference shock and last block is a technology shock

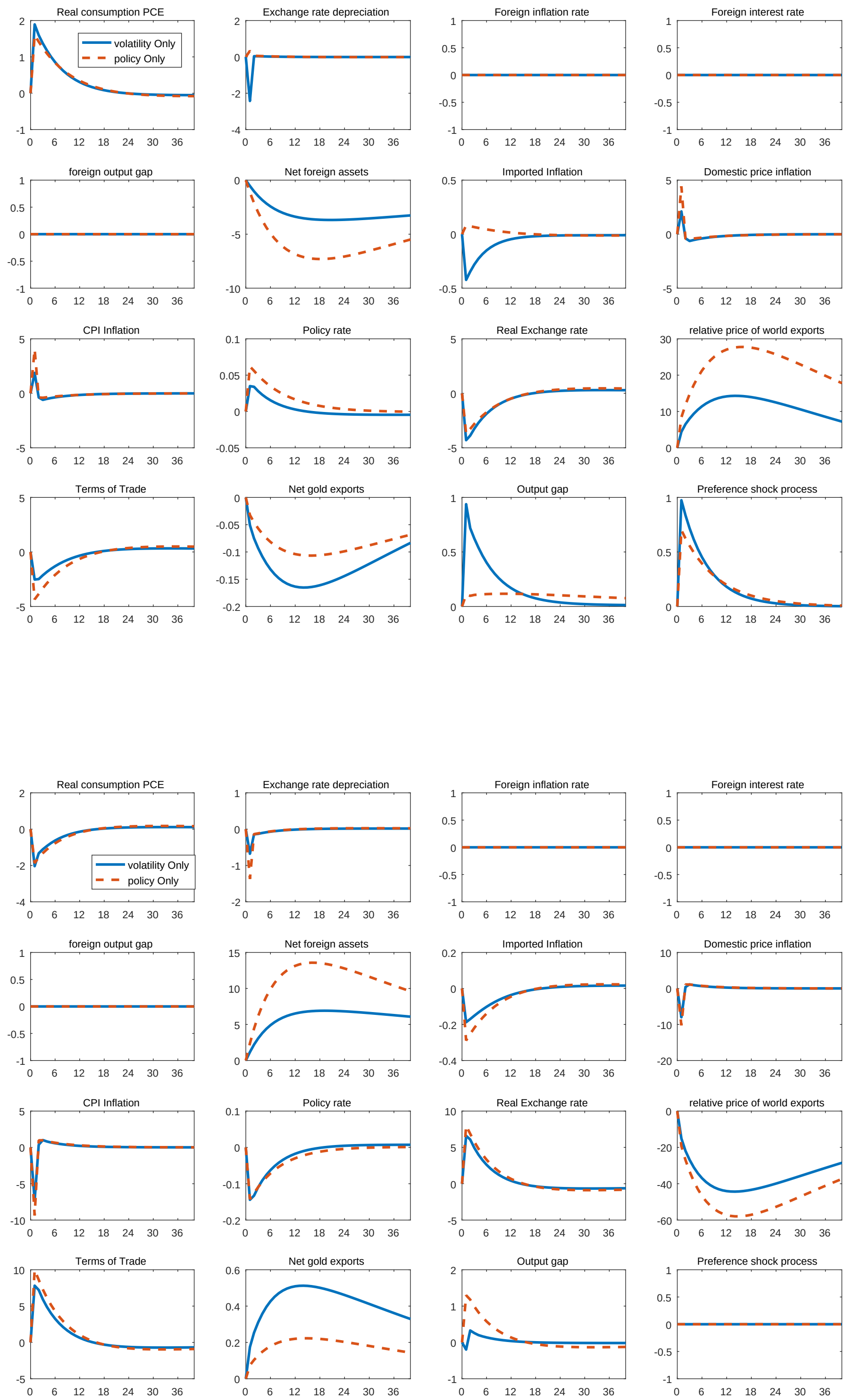


Figure 4.6: Dynamic responses to monetary policy regimes

Note: First block is regime 1 and last block is regime 2

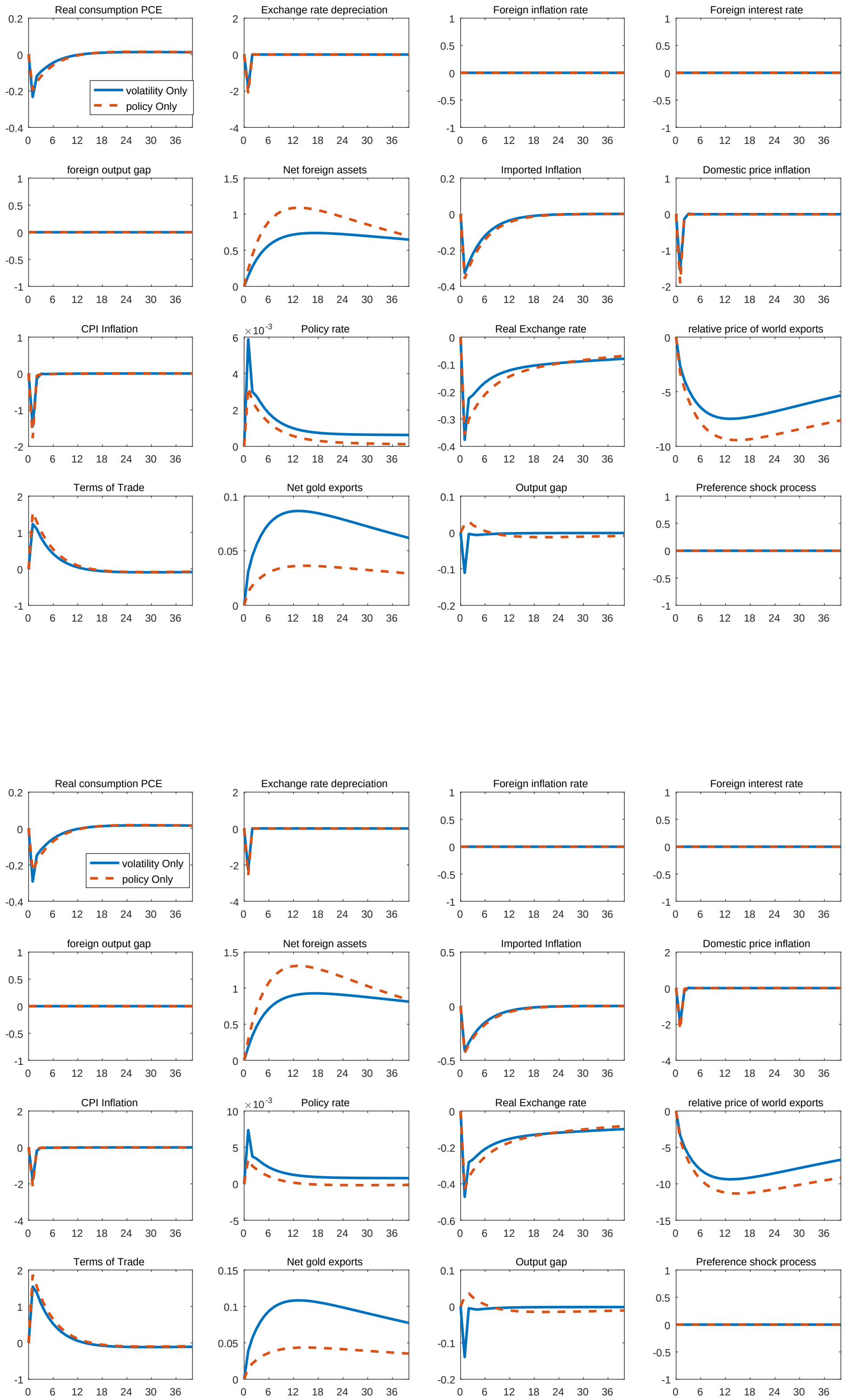


Figure 4.7: Dynamic responses to export shock regimes

Note: First block is regime 1 and last block is regime 2

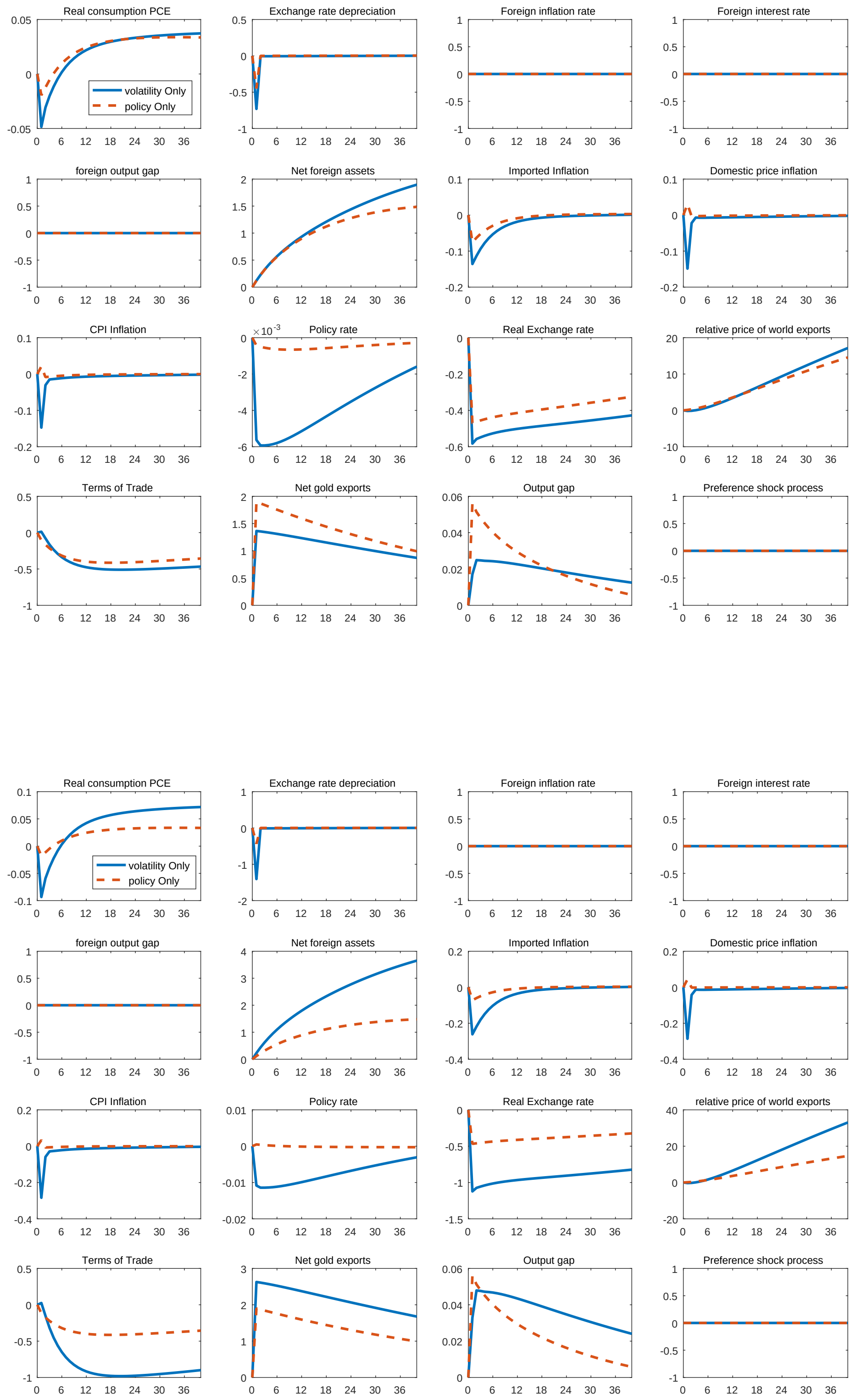


Figure 4.8: Dynamic responses of import-cost inflation regimes

Note: First block is regime 1 and last block is regime 2

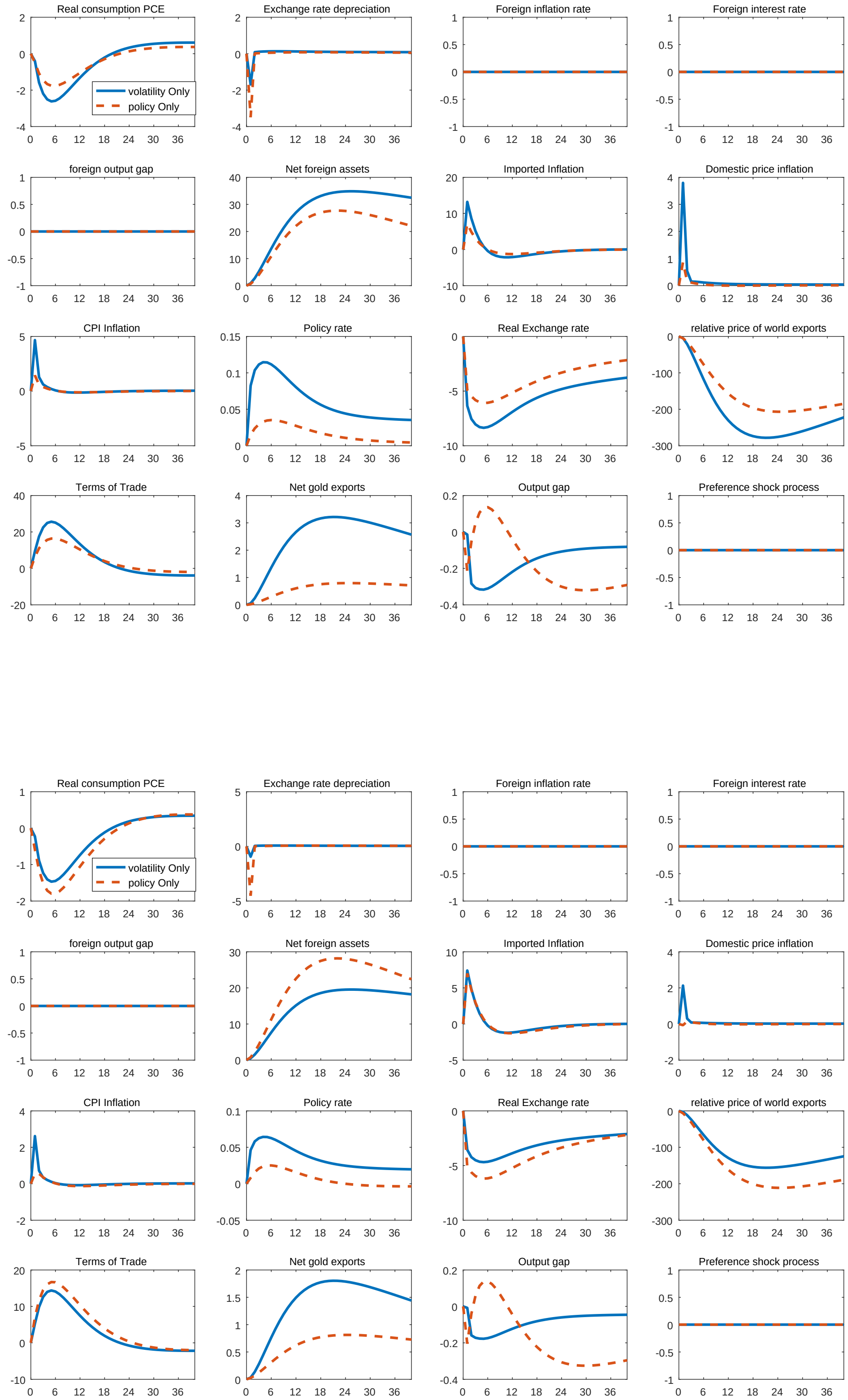
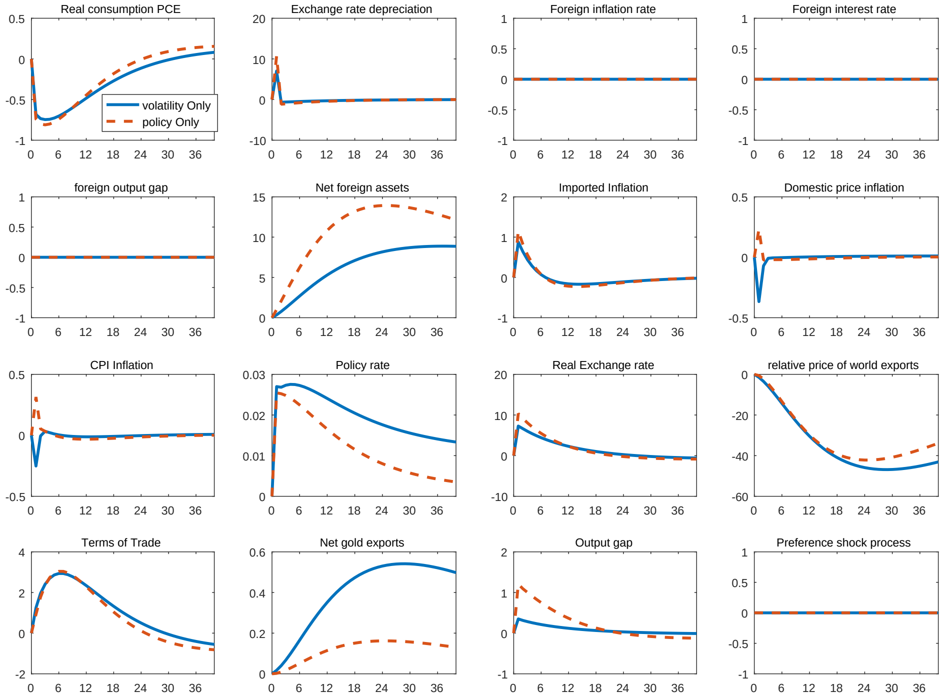


Figure 4.9: Dynamic responses of risk premia regimes

Note: First block is regime 1 and last block is regime 2



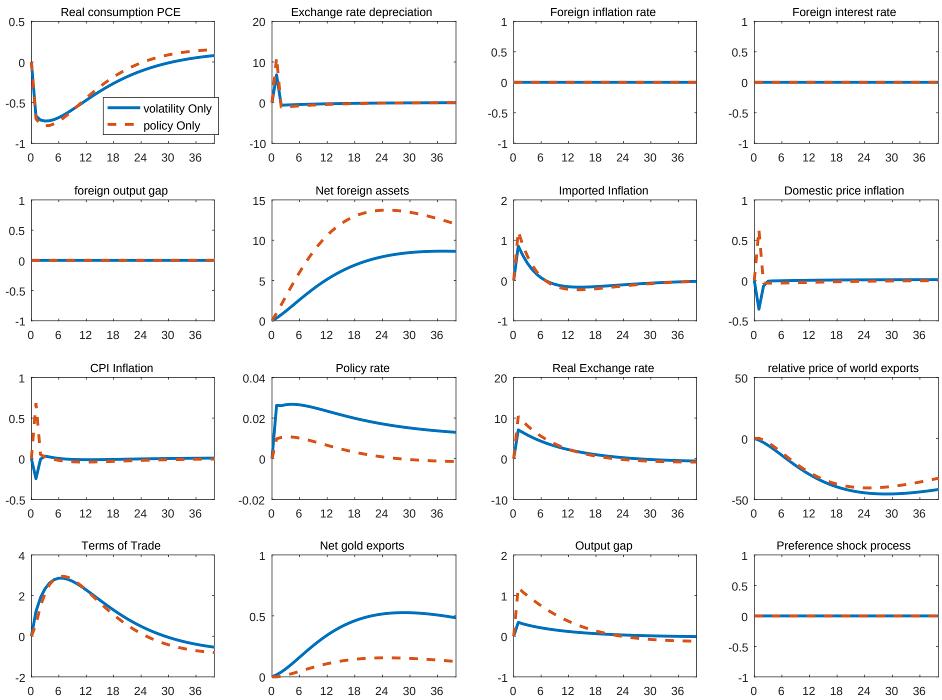


Figure 4.10: Variance deompositions of policy rate and CPI inflation

Note: Left panel is monetary policy rate and right panel is consumer price inflation

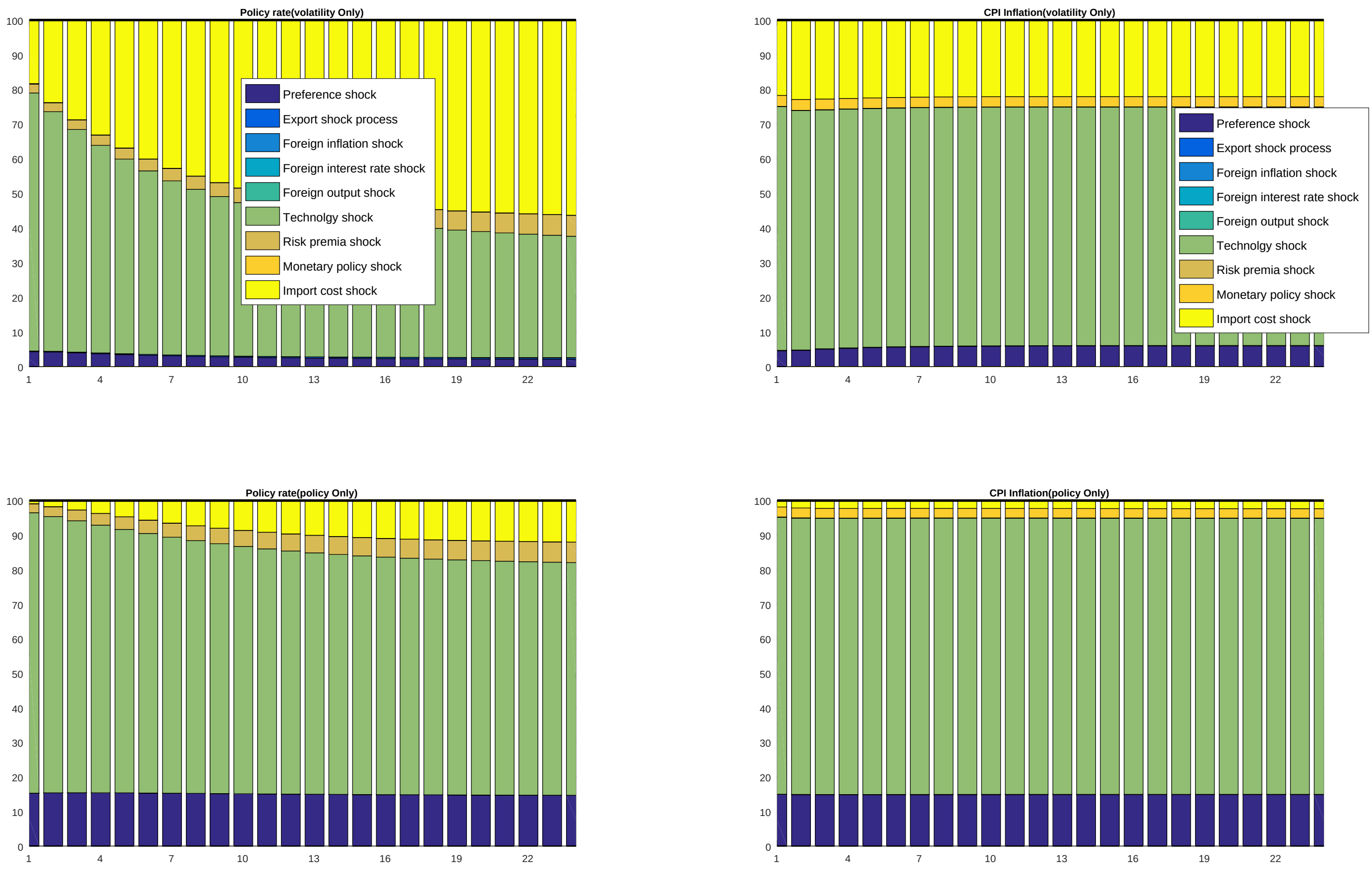


Figure 4.11: Variance decompositions of output gap and real consumption

Note: Left panel is output gap and right panel is real consumption

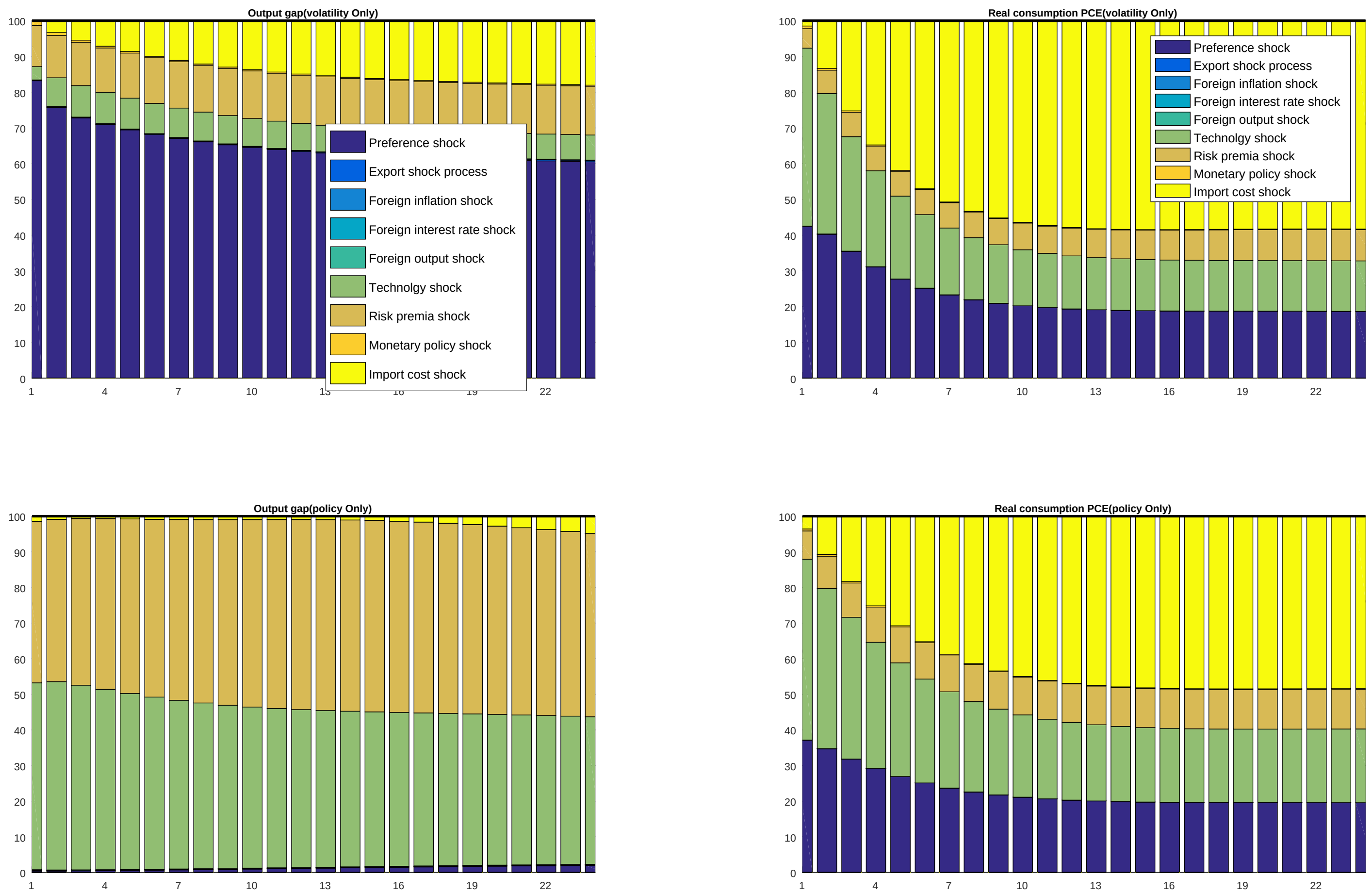


Figure 4.12: Variance decompositions of net gold exports and exchange rate depreciation

Note: Left panel is net gold exports and right panel is exchange rate depreciation

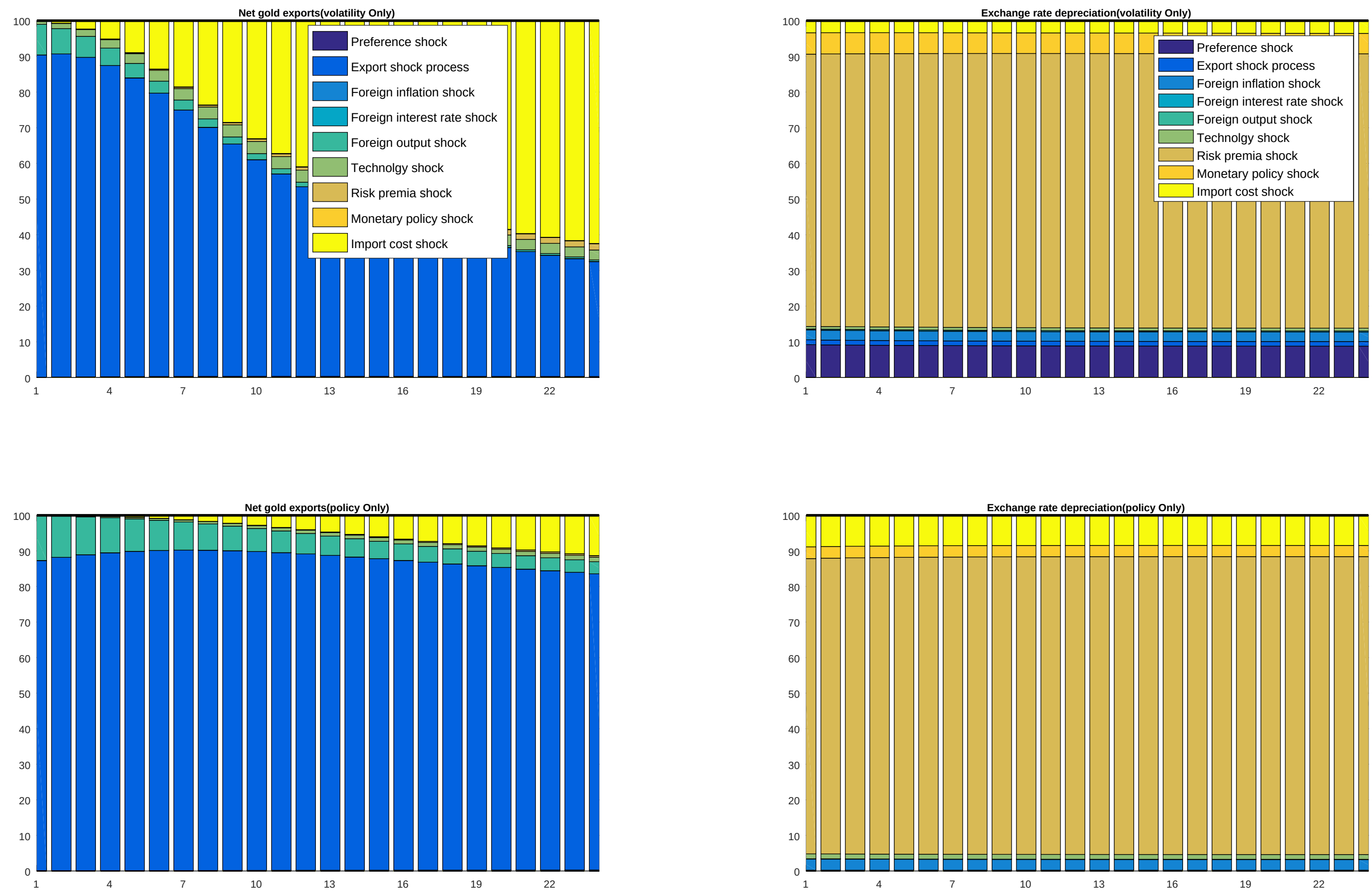


Figure 4.13: Historical decompositions of policy rate and consumer price inflation

Note: Left panel is monetary policy rate and right panel is consumer price inflation

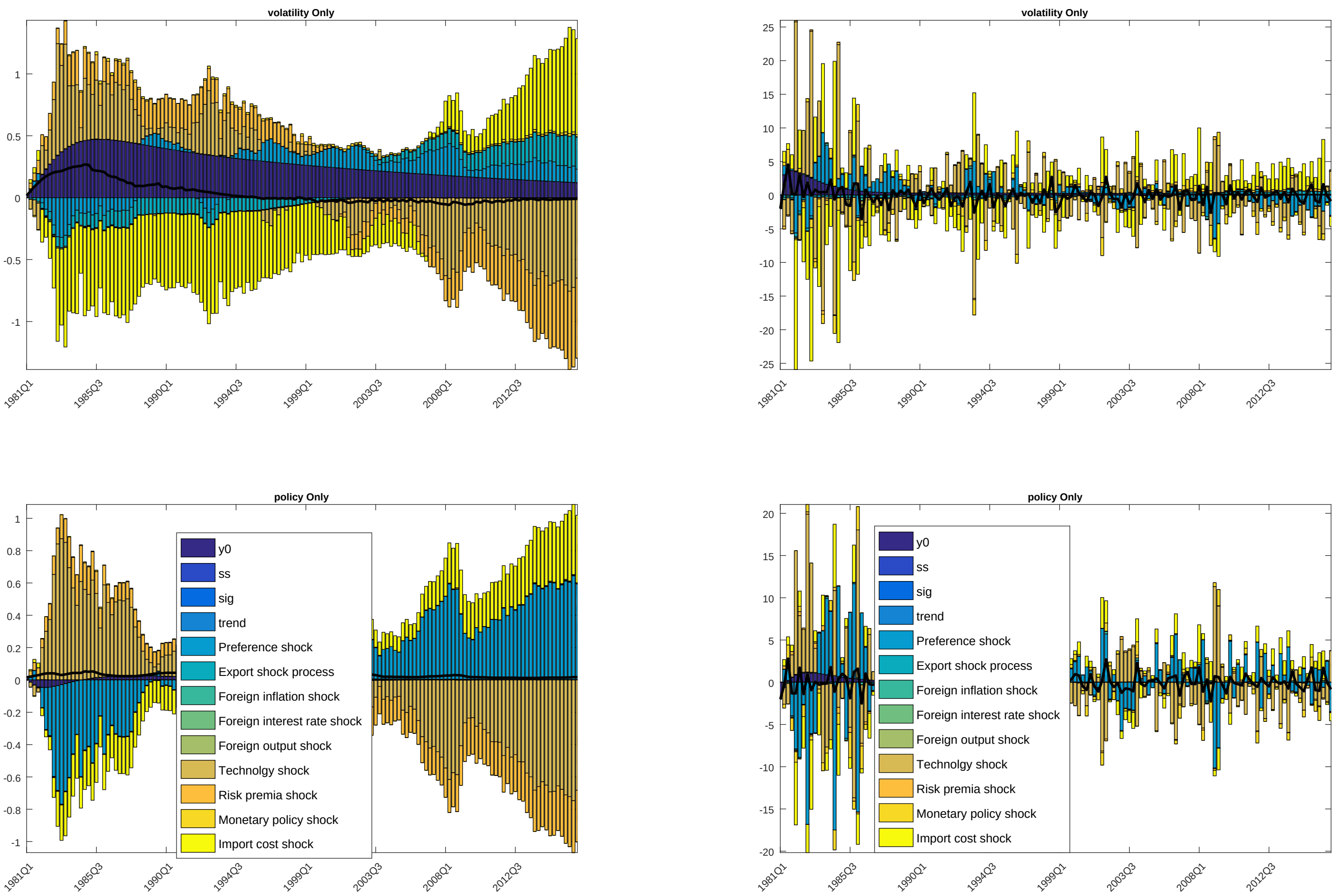


Figure 4.14: Historical decompositions of output gap and real consumption

Note: Left panel is output gap and right panel is real consumption

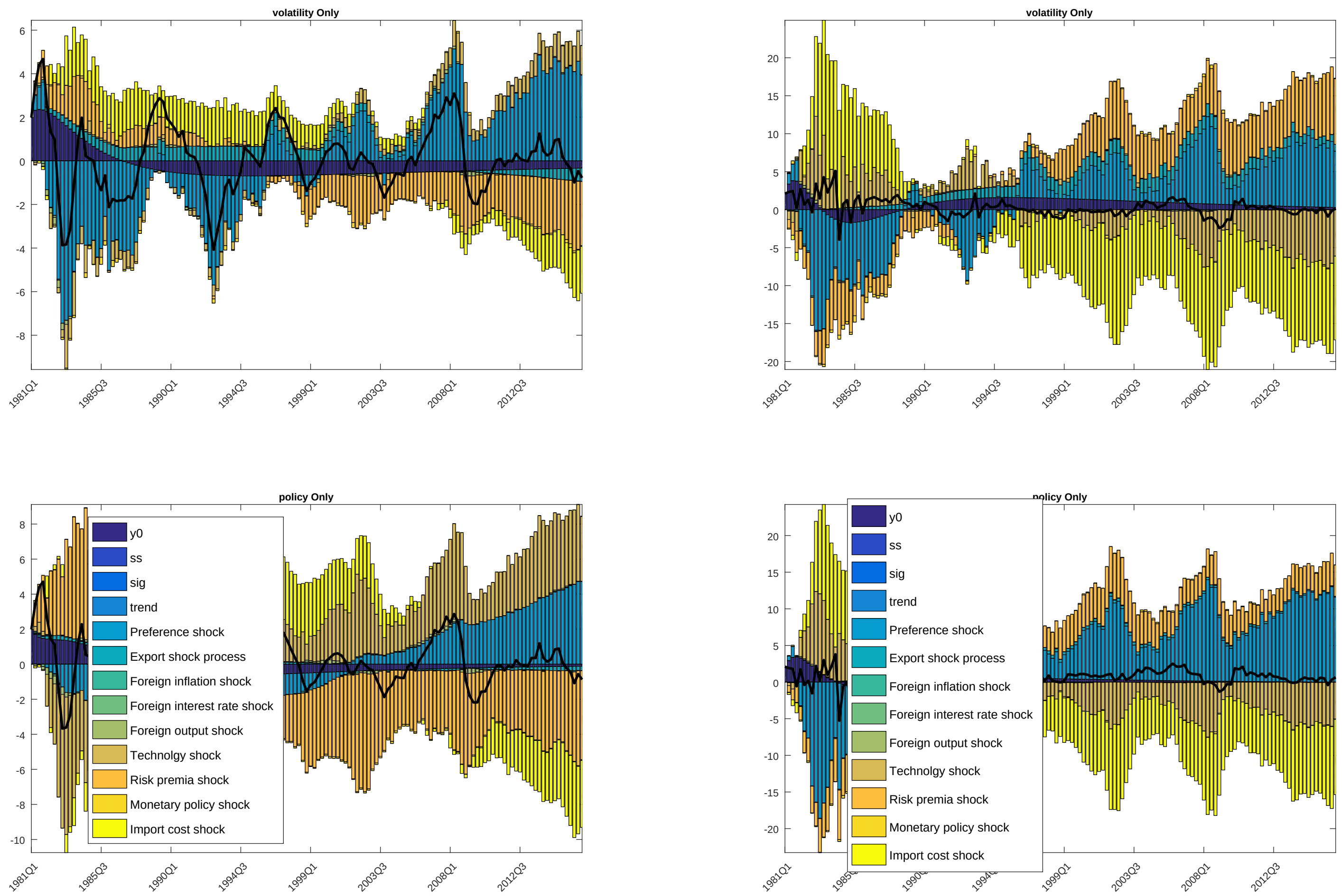
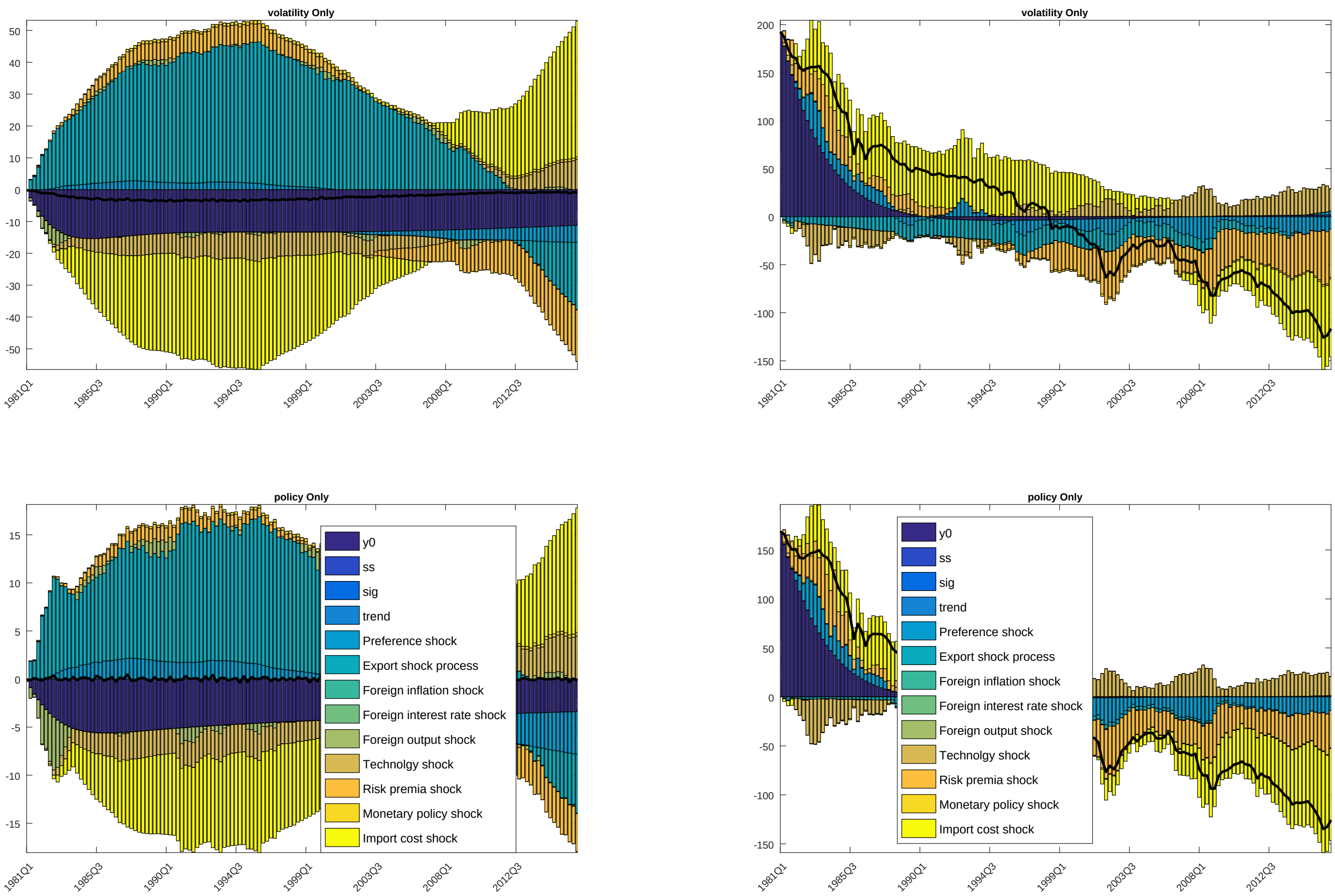


Figure 4.15: Historical decompositions of net gold exports and exchange rate depreciation

Note: Left panel is net gold exports and right panel is exchange rate depreciation



Chapter 5

Central Bank Credibility Following a Regime Change

5.1 Introduction

Over the last three decades, policy authorities and academic economists have advocated for an independent central bank with clear policy objectives to ensure their credibility. This is one of the underlining principles that motivates many developed and emerging economies with unstable inflation to adopt an inflation targeting regime. Whether central banks are credible and how credibility affects economic performance after adoption of inflation targeting regime is still an open debate. This chapter, therefore, tests whether the adoption of an inflation targeting regime improves policy authority credibility along with its associated effects on macroeconomic dynamics, using an example of an emerging economy, that of South Africa. For the purposes of this chapter, central bank credibility refers to the conduct in which a policy authority adopts a monetary policy framework and sticks to it, meaning that the policy authority says what it does and does what it says. Put differently, a policy authority is credible if economic agents believe it will do what it says (see Blinder (1999)).

Given this, there are three important reasons motivating a current investigation into this question. First, there is a debate as to whether credibility improves when a new policy framework is in place and how it generates positive macroeconomic outcomes. For example, Walsh (2011) and Taylor (2014) argue that the conduct of policy authorities is important in influencing economic agents' inflation expectations relative to institutional structures. Alternatively, Sargent (2012) and Cukierman (2013) contend that the gap between realised and target inflation stems from the degree of institutional evolution that then affects monetary policy credibility.

Secondly, regarding the South Africa situation, the inflation target calender year average was revised in 2002 to a medium-term target from November 2003. Moreover, the South African Reserve Bank switched its inflation target from the consumer price index excluding mortgage interest cost (CPIX) in 2008 to the overall consumer price index (CPI) in 2009. The reason is that rising interest rates increase mortgage costs and, in turn, increase inflation, which would lead to higher policy rates. However, if economic agents act on the basis of CPIX inflation while the SARB targets the CPI inflation, then CPI inflation is not a credible measure of inflation among economic agents. Lastly, following the adoption of an inflation targeting regime in South Africa from 2000 to 2008, the SARB on average is credible among economic agents based on a credibility indicator as shown in this chapter.[1] Between 2003 and 2007, the observed CPIX inflation remained within the inflation target band of 3 and 6 per cent. This trajectory had changed in early 2008. In most of the months in 2008 and 2009, CPI inflation exceeded the upper limit of the inflation target. Similarly, from 2011 to 2016 inflation was on an upward trajectory. This trend leads one to question the credibility of the SARB.

This issue is addressed in this chapter to determine how the dynamics of credibility evolves over time and, further, to reconcile some of the disparities in the literature. To effect this, a Markov-switching Bayesian vector autoregressive model with time-varying transition probabilities is used. This advances a unique way of

[1] See first top left panel of Figure 5.1 and top panel of Figure 5.3 for the statistics.

investigating the evolution of central bank credibility. This will determine which of the macroeconomic indicators have larger effects on the dynamics of policy credibility and the importance of these indicators.

The theoretical method used in this study follows Taylor (1993), Cecchetti and Krause (2002), Kozicki and Tinsley (2007) and De Mendonça and Souza (2009). Thus, the main contribution of this chapter to the literature is to incorporate Markov-switches with transition probabilities into the modeling framework in examining central bank credibility. These are able to capture the underlying unobserved dynamic of policy credibility. Previous studies that estimate central bank credibility are based on educated guesses and assume that the underlying parameters are time-invariant (see Montes (2009), Bordo and Siklos (2014) and Levieuge et al. (2015)). The underlying unobserved properties of policy authority credibility is estimated. This makes the approach more appealing and allows the data instead of the researcher to parameterise the model. Some authors recommend thinking of the measure of credibility as evolving over time and nonlinear (see Bordo and Siklos (2017) and Levieuge et al. (2015)). In this light, the evidence regarding the time path of credibility is provided, taking into account changes in macroeconomic conditions.

This thesis's findings suggest that most of the high variances in credibility occurred around 1990 and 2000, then are followed by the crisis in 2008 when the policy authority moved to a low credibility regime state. The dynamic responses show that a positive credibility shock generates a reduction in policy rate that leads to a decline in the inflation rate. Although real GDP does not react immediately, uncertainty in it increases, implying that economic agents are suspicious of sudden gains in policy authority credibility. This further suggests that a credible policy authority does not require frequent changes in the policy rate because it takes time to build credibility, which has a significant effect on monetary policy to stabilise inflation and output.

Another important finding is that inflation accounts for a larger amount of variability in credibility compared to variability in credibility due to the policy rate. This presupposes that private agents observe inflation changes and use this information to evaluate the degree of policy authority credibility in the South African economy. This result is related to the finding of Montes (2013), who finds that credibility impacts on the inflation expectations of private agents, which in turn affect investment and employment decisions.

The rest of the chapter is organised into six sections. Section 2 reviews related literature and section 3 discusses the theoretical approach underpinning the measure of central bank credibility. Section 4 outlines the econometric framework, data and stylised facts. Section 5 presents the empirical results and section 6 concludes the chapter.

5.2 Related Literature

Many authors have proposed varying descriptions of policy credibility. One of the most widely used descriptions is related to Kydland and Prescott (1977), Cukierman (1986), Ball (1994) and Blinder (1999). According to Cukierman (1986), policy credibility is a state in which economic agents accept policy authority objectives that are consistent with current economic conditions. Without this, economic agents will suspect any policy announcement that is not in line with policy objectives. Ball (1994) postulates that policy credibility is the reason for low inflation which leads to economic expansion. He argues that it is not the staggered price setting that is the main setback to disinflation, rather it is credibility. Although, this chapter is related in the most part to these definitions, it differs by allowing for a possible change in the level of policy credibility in a structural analysis to account for the unobserved policy credibility.

Another strand of the literature measures policy credibility and investigates how policy credibility affects macroeconomic stability. This study shares similar concepts of credibility in either the difference between inflation expectations and the target inflation rate or observed inflation and the target inflation rate.

Empirically, Bomfim and Rudebusch (2000) and Demertzis et al. (2008) quantify credibility and experiement with it on the U.S. economy. The central message is that commitment policy helps to reduce the length and cost of disinflation compared to discretionary monetary policy because commitment leads to credibility gains.

Similarly, Amisano and Tronzano (2010), Mariscal et al. (2011) and Kupfer (2015) use the Svensson (1993) test of inflation targeting credibility to understand financial markets' inflation expectations. Amisano and Tronzano (2010) and Kupfer (2015) use the test as an example on the European Central Bank credibility. The authors find that the European Central Bank anchored financial market inflation expectations. However, Kupfer (2015), identifies that inflation targeting is credible during a tranquil period as compared to a crisis period such as the recent financial crisis in 2008. Therefore, he proposes that during a crisis, one needs to account for a risk premium and liquidity effects. In the context of the Bank of England, Mariscal et al. (2011) use the same model and conclude that prior to the adoption of the inflation targeting regime in 1992 to 2007, the policy authority in the U.K. gained credibility but the Bank's credibility worsened thereafter.

This work differs from these authors in two ways. It explicitly allows the belief structure of credibility to change over time and derives its credibility indicator from the Taylor rule principle that measures credibility as a performance base. Although Amisano and Tronzano (2010) and Mariscal et al. (2011) use Bayesian inference, that is close to this thesis, the difference is that this complements the literature using time-varying transition probabilities that are capable of capturing the underlying unobserved dynamics of policy credibility. And thus progresses and makes a contribution to the existing structural literature on central bank credibility.

In this light, this chapter is related to Kozicki and Tinsley (2007), De Mendonça and Souza (2009) and Bordo and Siklos (2015), who use a panel method, OLS and a generalised method of moments to examine changes in the credibility of central banks. This thesis contributes to this literature when using a Markov-switching Bayesian vector autoregression with time-varying transition probabilities, as recommended by Bordo and Siklos (2015). They propose that an intuitive way of understanding the dynamics of policy authority credibility is to examine it in a nonlinear way and a regime-switching approach.

There are other studies that examine policy authority credibility from the perspective of dynamic stochastic general equilibrium models. These include among others, Debortoli and Nunes (2014), Goy et al. (2016) and Park (2016). They examine the Federal Reserve Board credibility in a Markov-switching dynamic stochastic general equilibrium framework in which the Board posseses commitment technology. The results do not favour either full commitment or discretion. Instead, the Board resets its policy objectives depending on the prevailing economic environment. Park (2016) investigates a measure of credibility and shows that credibility helps to stabilise macroeconomic fluctuations and influences the responses of inflation to policy shocks and lowers disinflation cost. He concludes that credibility gains reduce variability in inflation and output.

There are various studies that look at South African central bank credibility from different perspectives and using varying methodologies, such as micro data and time series properties, Rigobón (2007), Reid (2009), Kaseeram (2012), Kabundi et al. (2015) and Pierdzioch et al. (2016). The common finding is that the SARB is credible among financial markets inflation expectations but firms, trade unions and households show wide deviations from their inflation expectations and the target inflation. However, not much is known about the effects of central bank credibility on macroeconomic dynamics in South Africa. In this context, it is important to examine whether regime change contributes to central bank credibility gains and its effect on monetary policy transmission to inflation and output.

In addition, these authors recommend further investigations into this type of debate. In particular, Kaseeram (2012) and Kabundi et al. (2015) suggest that to adequately address a related question posed at the beginning of this chapter, that is, whether central banks are credible and its effects on the transmission of monetary policy to macroeconomic outcomes requires an alternative method. This is where this chapter becomes very relevant and important in the South African context, for it appears that no study has examined the evolving nature of credibility in the conduct of monetary policy using this approach.

5.3 Theoretical Approach

The seminal contribution of Taylor (1993) description of monetary policy conduct of the Federal Reserve Board evolves as

$$r_t = \overline{r}_t + \overline{\pi} + \alpha_1(\pi_t - \overline{\pi}) + \alpha_2(y_t - \overline{y}_t) + \mu_t, \tag{5.1}$$

where r_t is the nominal policy rate, $\overline{r}_t$ is the long run policy rate, $(\pi_t - \overline{\pi}_t)$ is a four-quarter moving average of observed GDP deflator less target inflation, $(y_t - \overline{y}_t)$ is a weighted average of real GDP gap and μ_t is the policy rate shock.

By inspection of eq. (5.1) that has five variables and two parameters, a possible policy failure emerges that explains the great inflation of the 1970s in three ways. First, changes in the responses of the policy parameters as estimated by Clarida et al. (2000). According to them, the responses of the policy rate was not consistent with the responses of the inflation rate. This shows that economic agents inflation expectations in the 1970s were not generated from macroeconomic fundamentals. Secondly, the proper characterisation of the policy authority perception of the natural rate of policy rate, inflation and output is problematic. Thus, a typical example is the lack of proper estimates of the policy authority's potential output. Finally, central banks attempt to exploit a perceived trade-off between inflation and output growth.[2] However, the weakness of these explanations lie in the lack of empirical estimates to recover the implied inflation target and the constraints on

[2]See, Nelson (2004) and Sargent (2012) for some of the discussion about the causes of the great inflation in the 1970s.

the scope of the policy rate responses to directly impact on output and inflation rate.

As a result, Kozicki and Tinsley (2007) develop an implied and effective inflation target rate on the assumption that in the absence of an inflation target and clear policy objectives, the true policy authority inflation target is achieved only in the outcome of the realised inflation rate. Secondly, policy decisions are based on the knowledge available at the time in which decisions were made. Therefore, the actual setting of the policy rate is a forward-looking specification of the form

$$r^*_{t,f} = \overline{r}_t + \overline{\pi}_t + \alpha_{1,t}(\pi_{t+k|t} - \overline{\pi}_t) + \alpha_{2,t}(y_{t+k|t} - \overline{y}_t) + \alpha_{3,t}\Delta y_{t|t}, \qquad (5.2)$$

where $r^*_{t,f}$ is the desired policy rate and $\pi_{t+k|t}$ is the expected inflation. $y_{t+k|t}$ and $\Delta y_{t|t}$ are the expected output and changes in forecast output. If the policy authority places a larger weight on output, then the desired dynamic reaction of the policy rate can be a function of the forecast changes in output growth of the form

$$r_{t,f} = \beta_{5,t}\Delta r_{t,f-1} + (1 - \beta_{6,t})r^*_{t,f} + \beta_{6,t}r_{t,f-1} + \eta_{t,f}. \qquad (5.3)$$

Here, the policy rate adjustment is based on previous period policy rate changes, partial adjustment of the policy rate to the desired policy setting and a disturbance term $\eta_{t,f}$.

Combining eqs.(5.2) and (5.3) yields

$$\begin{aligned} r_{t,f} = {} & \beta_{1,t} + \beta_{2,t}\pi_{t+k|t} + \beta_{3,t}(y_{t+k|t} - \overline{y}_{t|t}) + \beta_{4,t}\Delta y_{t|t} \\ & + \beta_{5,t}\Delta r_{t,f-1} + \beta_{6,t}(r_{t,f-1} - \overline{r}_t) + \overline{r}_t + \eta_{t,f}, \end{aligned} \qquad (5.4)$$

where $\beta_{1,t} = (1 - \alpha_{1,t} - \beta_{6,t} + \beta_{6,t}\alpha_{1,t})\overline{\pi}_t$, $\beta_{2,t} = (1 - \beta_{6,t})\alpha_{1,t}$, $\beta_{3,t} = (1 - \beta_{6,t})\alpha_{2,t}$ and $\beta_{4,t} = (1 - \beta_{6,t})\alpha_{3,t}$. Then the parameters in eq. (5.4) are mapped to the structural parameters and unobserved inflation target in eqs. (5.2) and (5.3) to yield policy authority implied inflation target of the form

$$\overline{\pi}_t = \frac{-\beta_{1,t}}{\beta_{2,t} + \beta_{6,t} - 1} \qquad (5.5)$$

Further, Kozicki and Tinsley (2007) show that in economies where a monetary aggregates target was in place before inflation targeting regime, an effective inflation target can be derived as

$$\overline{\pi}_t^e = \Delta\overline{m}_t - \Delta\overline{y}_t + \Delta\overline{v}_t \tag{5.6}$$

where $\overline{\pi}_t^e$ is an effective inflation target, $\Delta\overline{m}_t$ is the target growth rate of money supply, $\Delta\overline{y}_t$ is the natural rate of output and $\Delta\overline{v}_t$ is the trend velocity of money. This implies that an effective inflation target is increased when there is a reduction in the natural rate of output and increases in money growth and the velocity of money. This is the strategy used to estimate the inflation target from 1986 to 1999, where the SARB practised monetary aggregates targeting.

Following this theoretical approach, the credibility indicator is obtained based on a measure developed by Cecchetti and Krause (2002) and modified by De Mendonça and Souza (2009), this takes the form

$$CI_t = \begin{cases} 1 & \text{if } \pi_{t+1|t} = \overline{\pi}_t \\ 1 - \dfrac{1}{\pi_t^* - \overline{\pi}_t}[\pi_{t+1|t} - \overline{\pi}_t] & \text{if } \pi_{t,min}^* < \pi_{t+1|t} < \pi_{t,max}^* \\ 0 & \text{if } \overline{\pi}_{t,max} \leq \pi_{t+1|t} \leq \overline{\pi}_{t,min} \end{cases}$$

where CI_t is the credibility indicator that has value 1 when expected inflation ($\pi_{t+1|t}$) or observed inflation equals inflation target $\overline{\pi}_t$ and decreases linearly if the expected inflation ($\pi_{t+1|t}$) or observed inflation deviates from the inflation target $\overline{\pi}_t$. Whereas π_t^* is the inflation target range which has upper and lower limits. The target range allows the central bank the degree of flexibility to absorb shocks outside its control. The shocks include the first-round effects of supply shocks, the appropriate time period to restore inflation within the target range and the interest rate smoothing over the business cycle.

This implies that in the periods when a central bank credibility is strict, credibility remains within the range of 0 and 1 when expected inflation ($\pi_{t+1|t}$) or observed inflation remains within the maximum and minimum limit of inflation π_t^*, and 0 when it exceeds the limit of inflation π_t^* established by the central bank's internal arrangement. Although there are various credibility indicators that have been proposed in the literature, the reasons for the adoption of the Cecchetti and Krause (2002) measure are: in the policy credibility literature this measure is popular and has been used in many empirical works. Similarly, the measure is capable of capturing changes in credibility consistent with an inflation targeting regime and disciplines policy authorities when inflation deviations from the inflation target. Finally, the measure is simple to compute and has intuitive understanding of changes in credibility.

Given the credibility indicator, the policy authority is credible if and only if, it delivers on the inflation target conditional on economic, institutional and financial stability factors that may have influenced policy credibility, as shown in the three possible explanations in the 1970s great inflation period. Therefore, the model equation is formalised as[3]

$$CI_t = \psi CI_{t-1} + \phi z_t + \varepsilon_t, \tag{5.7}$$

where ψ is credibility persistence and ϕ is a vector of parameters. z_t captures macroeconomic, financial and institutional stability variables that affect policy authority credibility and ε_t is the error term. In this paper, however, the main focus is on macroeconomic stability variables, such as policy rate, inflation and output growth.

[3]The one period ahead expected inflation is used because it is mostly assumed that monetary policy is conducted over a short time horizon. Typically, in the forward looking policy rule literature, the k-period ahead forecast of inflation is usually twelve month when using monthly data or 4 quarters ahead when using quarterly data, see Clarida et al. (1998) for a brief discussion. (Clarida R, Gali, Gertler M (1998) Monetary policy rules in practice: Some international evidence. Eur. Econ. Rev. 42, 1033 1067)

5.4 Method, Data and Stylised Facts

5.4.1 Econometric Method

Eq. (5.7) is modeled as a regime-switching with time-varying transition probabilities of policy credibility following Filardo (1994) and Filardo and Gordon (1998). According to them, a Markov-switching vector autoregression model with a time-varying transition probabilities takes a reduced-form as

$$x_t = c(s_t) + B_1(s_t)x_{t-1} + ...B_p(s_t)x_{t-p} + \mu_t, \tag{5.8}$$

where x_t for $t = 1, \ldots, T$ is an $M \times 1$ vector of all endogenous variables and x_{t-1} is $M \times 1$ vector of all exogenous variables. The matrices $c(s_t)$ and $B(s_t)$ are functions of the model parameters. These assume S-state Markov chain s_t with a time-varying transition matrix governed by P probability matrix of the form

$$P(S_t = s_t | S_t = s_{t-1}, g_t) = \begin{pmatrix} p(g_t) & 1 - q(g_t) \\ 1 - p(g_t) & q(g_t) \end{pmatrix}, \tag{5.9}$$

where $p(g_t)$ is the time-varying transition probability in state 1 and $[1 - p(g_t)]$ is the movement from state 1 to state 2. $q(g_t)$ is the time-varying transition probabilities in state 2 and $[1 - q(g_t)]$ is the movement from state 2 to state 1. g_t is the past values of the economic indicators and are obtained through the unobserved variables. This is required to avert endogeneity bias and to show that economic indicators are observed at the end of the period.

The transition probabilities are obtained by transforming the cummulative distribution function (CDF) into a standard normal distribution to yield

$$p(g) = prob(S_t = 1 | s_t = 2) = \phi(-\alpha_0 - \alpha_1 g_{t-m}), \tag{5.10}$$

$$q(g_t) = prob(S_t = 2 | s_t = 1) = 1 - \phi(\alpha_0 - \alpha_1 g_{t-m} - \alpha_2), \tag{5.11}$$

S_t are the observed state variables that take the form

$$S_t = \alpha_0 + \alpha_1 g_{t-m} + s_{t-1} + \omega_t, \tag{5.12}$$

where α measures the effect of the frequency of the regimes and the information content of the economic indicators g_t. When $\alpha_1 = 0$, the model reverts to constant transition probabilities.

Eqs. (5.8), (5.9) and (5.12) form the MS-VAR and is estimated conditional on the joint densities which nest the information in the data and the time-varying transition probabilities to the estimation method.

In estimating the MS-VAR, Bayesian inference is carried out which combines the prior densities with the likelihood function to estimate the posterior densities using Gibbs sampler. Because a straightforward estimation of the MS-Bayesian VAR is complicated, it is circumvented by adopting a two-step estimation procedure. First, the BVAR based on the path of the observed state variables is estimated. This is then followed by estimating the transition probabilities and the frequency of the regimes, given the BVAR parameters. The VAR takes the form

$$X_t = Z_t\beta_t + \varepsilon_t \quad \varepsilon_t \ is \ i.i.d. \sim N(0, I_t), \tag{5.13}$$

where X_t for $t = 1, \ldots, T$ is an $M \times 1$ vector of observed variables and Z_t is $M \times k$ a matrix containing an intercept and p lags of each of the observed variables and $k = M(1 + \rho M)$. β_t are the model parameters and ε_t is the stochastic shock which follows an identically independent distribution.

Following Bańbura et al. (2010), the prior densities of the Bayesian VAR through a dummy observation approach is initiated. It then follows that the dummy observations matrix yield

$$X_d = \begin{pmatrix} \frac{diag(\delta_1\sigma_1 ... \delta_m\sigma_m}{\lambda} \\ 0_n(p-1) \times n \\ \cdots\cdots\cdots \\ diag(\sigma_1, ..., \sigma_m \\ \cdots\cdots\cdots \\ 0_1 \times m \\ \frac{diag(\delta_1\nu_1 ... \delta_m\nu_m}{\lambda} \end{pmatrix}, Z_d = \begin{pmatrix} \frac{J_p \otimes diag(\delta_1\sigma_1, ..., \delta_1\sigma_m}{\tau} & 0_{mp\times 1} \\ \cdots\cdots\cdots & \cdots\cdots \\ 0_{m\times mp} & 0_{m\times 1} \\ \cdots\cdots\cdots & \cdots\cdots \\ 0_{1\times m} & \xi \\ \frac{1 \otimes diag(\delta_1\nu_1, ..., \delta_m\nu_m}{\tau} & 0_{m\times 1} \end{pmatrix}, \tag{5.14}$$

Eq. (5.14) helps to pin down the autoregressive parameters in the dummies prior matrix of X_d and the intercept and variance covariance prior matrix of Z_d. $\delta_1, ..., \delta_m$ restrict the tightness of the priors on the first lag and $\sigma_1, ..., \sigma_m$ are the diagonal elements of the variance covariance matrix of eq. (5.13) and $\nu_1, ..., \nu_m$ are the means of the vector X_t. The parameters λ and τ restrict the VAR variables not to depend on the processes and the prior parameters. The values of $\lambda = 0.2$ and $\tau = 1$ are set with loose priors of the constant $\xi = 0.001$. This transforms the VAR to yield.[4]

$$X_t^* = Z_t^* \beta_t + \varepsilon_t^* \quad \varepsilon_t^* \ is \ i.i.d. \sim N(0, I_t^*). \tag{5.15}$$

After this, the Gibbs sampler is initiated. This follows the procedure as: first, the Markov process regime probabilities matrix $[0 - 1]$ is drawn using the Baum-Hamilton-Lee-Kim filter and smoother to obtain the regime probabilities. The draws are based on standard forward filter and backward sampling algorithms. Secondly, the Markov transitions matrix is drawn conditional on other parameters that take draws from the Dirichlet posterior densities.

Thirdly, the regression procedure is updated conditional on the state-space approach and the Markov-switching process to estimate the number of regimes in the model. Fourthly, the error variance covariance from the inverse Wishart distribution is drawn conditional on step three and, finally, the parameters of the model for the observed variables from their multivariate normal posterior densities are drawn.

5.4.2 Data

Firstly, the identification strategy is discussed, followed by data description. In this thesis, the researcher undertakes two identification strategies in relation to the Bayesian VAR and the switching regimes. In the BVAR ordering, generalised

[4] Note: Detailed derivations can be found in Bańbura et al. (2010). For a brief history of dummy observations see http://sims.princeton.edu/yftp/DummyObs/DumObsPriorSlides.pdf.

dynamic responses are employed. These are invariant to the ordering of the variables in the model. To identify a high and a low credibility regime, it is proposed that regime 1 is a low credibility regime in that monetary aggregates regime was in place and regime 2 is a high credibility regime following an inflation targeting regime.

South African quarterly data from 1986:Q1 to 2016:Q3 is used. The choice of the beginning sample point is motivated by monetary aggregates targeting first introduced in 1986. This study data is sourced from the IMF International Financial Statistics and the South African Reserve Bank databases. The variables used are real GDP, consumer price index inflation, policy rate and credibility indicator. The log difference of the real GDP seasonally adjusted and consumer price index are taken to capture their growth rates. Policy rate is measured as a percentage per annum and is the SARB's repurchase rate (repo rate).

Following Cecchetti and Krause (2002), who use an inflation target of 2 per cent in their original model as is a normal practice in the literature to ensure international comparison, and inflation limit of 20 per cent to show that once policy authority exceeds this limit, it looses control over inflation. In this thesis, credibility indicator is measured using a realised inflation rate and the mid-point of the SARB medium-term inflation target of 4.5 per cent over the inflation targeting regime and the mid-point of an effective inflation target is used in the monetary aggregates regime. To obtain an effective inflation target in a monetary aggregates regime, eq. (5.6) is used and in an inflation targeting regime the SARB medium-term inflation target bands are used.

With respect to the inflation limit, a 20 per cent limit in the monetary aggregates regime is set similar to Cecchetti and Krause (2002). The reason for this is that a monetary aggregates regime is characterised by high inflation and the primary goal of policy authority is not directed towards only price and economic stability. Whereas in an inflation targeting regime, an inflation limit of 10 per cent is used consistent with Montes (2013), who conducted a similar study for Brazil.

Moreover, in an inflation targeting regime, the SARB primary policy objective is price stability with a balanced and sustainable economic growth.

5.4.3 Stylised Facts

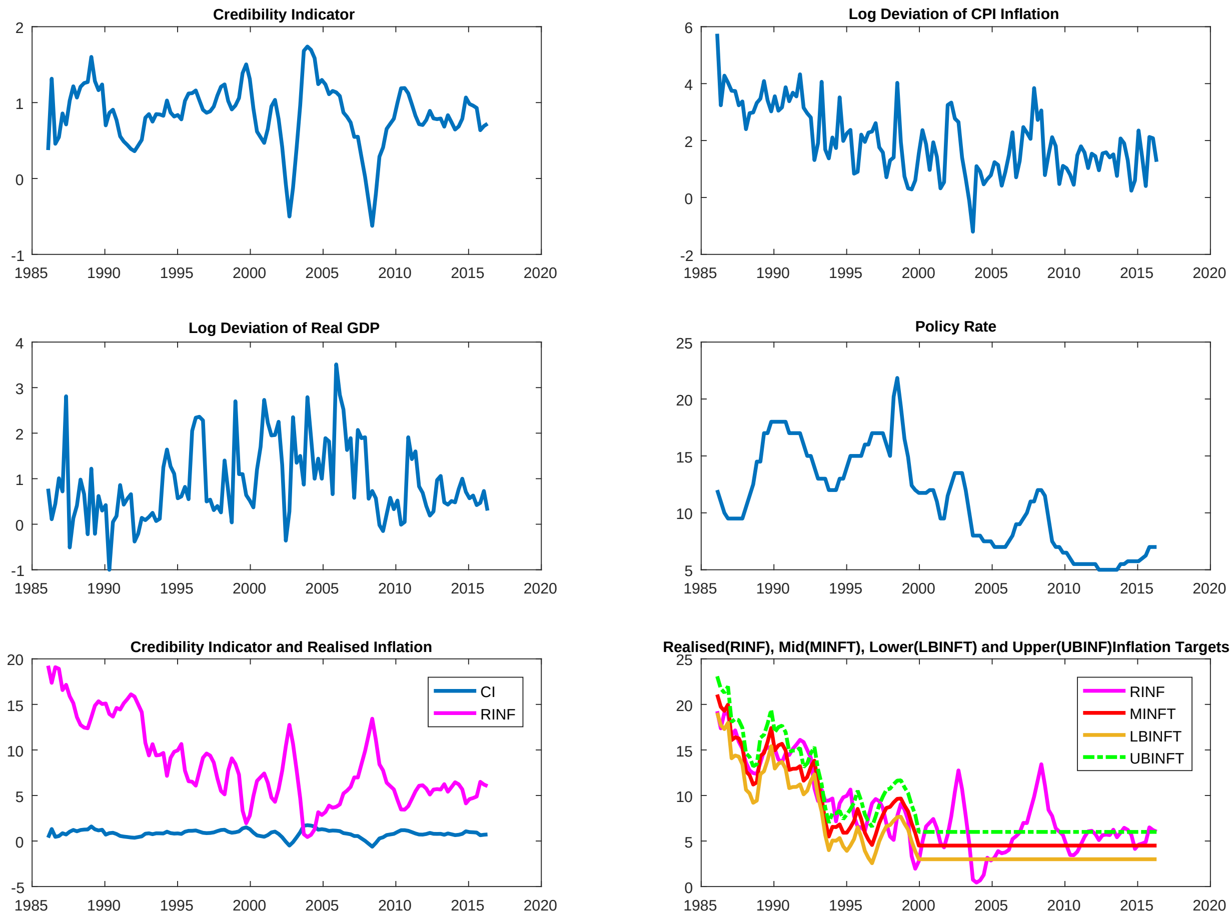
This section describes briefly the time series properties, but particular attention is paid to the discussion of a credibility indicator. Further, diagnostic tests in the form of a unit root, Johansen's cointegration test, Granger causality test and a simple regression estimates are conducted to identify the stability of the series and whether the series have the appropriate signs, a priori, to reduce spurious conclusions in the generalised dynamic responses.

5.4.3.1 Descriptive Statistics

Figure 5.1 plots the evolution of credibility and macroeconomic indicators. The top left panel of Figure 5.1 is credibility. It is found in the monetary aggregates regime that a credibility indicator behaves well and mostly remains stable within a credibility threshold of 1 and 0. However, the SARB credibility worsened in 1992 as a result of the political struggle leading to the 1994 general election.

During the unofficial inflation targeting in 1998, the Bank's credibility increased and remains the highest in the monetary aggregates regime. After the announcement of explicit inflation targeting, credibility deteriorated in 2001 as a result of the depreciation of the rand against the U.S. dollar by about 20 per cent over the last quarter of 2001. This trend is very similar to that discovered in Mariscal et al. (2011), who find that once inflation targeting regime was announced in the U.K., economic agents were optimistic that policy authority would deliver on its inflation target. However, when the Bank of England failed to deliver its target within the short term period, economic agents discredited the Bank's ability to deliver on the annouced inflation target.

Figure 5.1: Evolution of credibility and macroeconomic indicators



Over an inflation targeting regime, 2001 and 2008 are identified as the low credibility periods. Credibility falls below the lowest threshold of zero (0). The possible sources contributing to this pattern of a low credibility was the exchange rate shock in 2001 and the oil price shock that peaked in 2008, coupled with the financial crisis in 2008. This resulted in a tight monetary policy stance. The policy rate peaked at 13 and 12 per cent in 2001 and 2008, respectively. Realised inflation also peaked at 12 and 13 per cent during the same periods. This contracted the real GDP growth rate from 4.2 per cent in 2001 to 2.7 per cent in 2002 and also from 5.6 per cent in 2006 to negative 1.5 per cent in 2009. The periods 2001 and 2008 can be described as those in which the SARB experienced most rapid deterioration in credibility. This suggests that credibility matters in an inflation targeting regime.

From 2002, credibility gains could be observed until the global financial crisis set in. Policy rate declined from 12 per cent in 2002 to about 5 per cent in 2006. This led to a decline in the inflation rate from 14 per cent in 2002 to about 3 per cent in 2006, which stimulates real GDP growth to 5.6 per cent in 2006. In general, this period accounted for high credibility gains and the SARB delivered on its inflation target as reported in the bottom right panel of Figure 5.1. In most of the periods, inflation remained within the target band. Credibility picked up from 2010 and stabilised between 2012 and 2014, around an average of 0.8. This trend may account for relative stability in the policy rate and inflation over this period.

A similar pattern emerges in the summary statistics reported in Table 5.1. Over the monetary aggregates regime, average credibility was high compared to an inflation targeting average of 0.92 and 0.76, respectively. However, the uncertainty associated with monetary aggregates regime is high with a standard deviation of 0.29 far from its mean compared to the inflation targeting regime with a standard deviation of 0.49 relatively close to its mean, as reported in Table 5.1. The correlation coefficients of credibility with respect to the policy rate and

Table 5.1: Summary statistics

	Credibility			Inflation	Policy Rate	GDP
	Full Sample	Regime 1	Regime 2			
Mean	0.83	0.92	0.76	1.97	11.10	0.91
Median	0.85	0.90	0.78	1.81	1.50	0.66
Std. Dev.	0.42	0.29	0.47	1.19	4.26	0.84
Correlation				-0.22	-0.04	0.05
Obs.	123	56	67	123	123	123

Note: Regime 1= monetary aggregate regime and regime 2=inflation targeting regime. Inflation is log deviation of CPI, and GDP is log deviation of real GDP Source: author's estimation March 17, 2017

inflation show that credibility is negatively correlated with policy rate and inflation in Table 5.1. This means that an increase in credibility leads to a reduction in the policy rate and inflation, which is consistent with the dynamics of credibility channel of monetary policy transmission mechanism.

Lastly, the posterior densities from the Bayesian estimates used in this study are examined in Figure 5.3 of Appendix C 5.7.2. As revealed in the top panel of Figure 5.3, the posterior mean value of 0.68 suggests that on average policy authority is credible across regimes. Although the standard deviation of 0.20 is far from the mean, nearly all the observations are within a one standard deviation. This suggests economic agents are excessively optimistic about credibility of the SARB, and in some periods are overly pessimistic about the SARB conduct.

In the bottom panel of Figure 5.3, real GDP depicts a Gausian distribution fairly with posterior densities of 0.66 and 0.77 for the mean and the standard deviation. However, real GDP is characterised by high uncertainty compared to the consumer price index inflation and the policy rate, as reported in the middle panels of Figure 5.3.

5.4.3.2 Diagnostic Tests

In the previous section, the evolution of the variables was observed. One important assessment is the stability of the variables. Hence, unit root, Johansen's cointegration and Granger causality tests are conducted. As reported in Table 5.3 of Appendix C 5.7.1, the unit root test, using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) indicates that, after taking the log deviations of the consumer price inflation and real GDP, the series are stationary at all relevant levels of marginal significance and similarly credibility indicator in levels. However, the policy rate remains nonstationary at an even 10 per cent marginal significance level, as reported in Table 5.3.

This prompted an experiment with the Johansen's cointegration test as to whether the series have a long run relationship. If so, there would be no need to transform the policy rate series. The results in Table 5.4 of Appendix C 5.7.1 show that there exists at least one long run relationship among the variables. This means that the policy rate can be used without differencing it in the estimation.

Regarding the Granger causality test reported in Table 5.5 of Appendix C 5.7.1, the ordering of the variables are credibility, policy rate, inflation and real GDP. These suggest that credibility interacts with inflation but less with policy rate and real GDP. Based on this ordering, the regression results in Table 5.2 and the generalised dynamic responses in Figures 5.4 to 5.6 of Appendix C 5.7.2 were obtained.

Table 5.2 reports the OLS and GMM parameter estimates. These allow for an assessment of the signs and statistical significance of the parameters of the variables. This provides a naive way of observing the impact of the policy rate, inflation and real GDP on credibility. With respect to the estimates of the current policy rate, interestingly, all the alternative specifications indicate that the current policy rate parameters have an inverse relationship with credibility, as reported in Table 5.2. Similarly, an increase in inflation results in a loss of credibility.

Therefore, pressures from policy rate and inflation to the movements of pol-

Table 5.2: Regression estimates: Dependent variable credibility

	1		2		3	
Regressor	OLS	GMM	OLS	GMM	OLS	GMM
Constant	0.21(0.07)	0.21(0.07)	0.14(0.07)	0.13(0.06)	0.25(0.07)	0.25(0.07)
$Cred.Ind_{t-1}$	0.83(0.05)	0.82(0.06)	0.87(0.05)	0.88(0.06)	0.84(0.05)	0.84(0.06)
$PolRate_t$	-0.01(0.01)	-0.01(0.01)	-0.08(0.02)	-0.08(0.04)	-0.04(0.02)	-0.04(0.03)
$PolRate_{t-1}$			0.08(0.02)	0.08(0.04)	0.04(0.02)	0.04(0.03)
$Inflation_t$					-0.09(0.02)	-0.09(0.03)
$RealGDP_t$					-0.03(0.02)	-0.03(0.02)
Adj. R^2	0.69	0.69	0.72	0.72	0.77	0.77
$F-test$	132.72		102.27		75.57	
$J-test$		0.00056		0.00032		0.00018
$\chi^2(p-val)$		0.103		0.352		1.15

Source: Author's estimation March 17, 2017 Note: OLS= ordinary least squares, GMM=generalised method of moments, Standard errors are in parentheses

icy authority credibility exist. In addition, when the persistence of credibility is taken into account in line with theoretical considerations, credibility persistence is positive and statistically significant at 1 per cent marginal significance level. The adjusted R^2 and F_{test} show that jointly the variables are significant in explaining the variability in credibility. Similarly, when using the J_{test} for the GMM estimates, it fails to reject the validity of no overidentifying restrictions, and thus the overall specification of the model and the set of its instruments are valid.

5.5 Empirical Results

Estimated results are reported in the following order. Firstly, the regime switches in credibility is presented and it allows for the detection of the number of switches in credibility and how credibility has evolved over the sample period. Following this, the generalised dynamic responses for the full sample and the two monetary policy regimes are presented to examine the possible transmission channels.

5.5.1 Regime Switches in Credibility

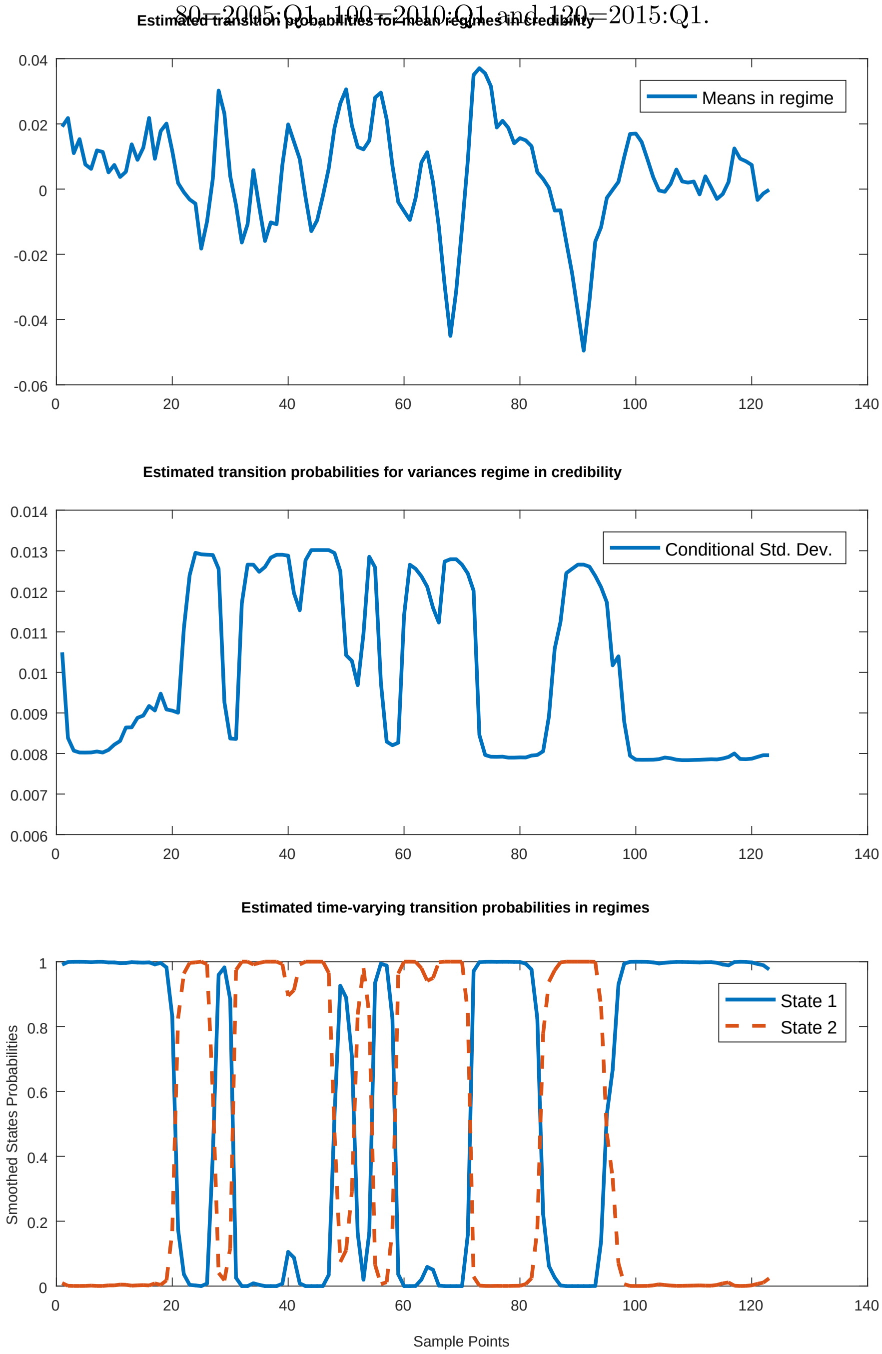
To empirically determine the validity of the descriptive findings that the SARB is credible, the estimates from the smoothed transition probabilities are used. Figure 5.2 presents the estimated smoothed transition probabilities for a mean credibility indicator in the top panel, the variance of a credibility indicator in the middle panel and a time-varying transition probabilities regimes in the bottom panel[5]. A noticable feature of the series plot of the smoothed probabilities regimes of the means and high variances of credibility indicator is that the values are erractic in nature.

The estimates of the means credibility plotted in the top panel of Figure 5.2 is capable of tracking the major periods in which the SARB lost credibility. These dates include 1992, 2001 and 2008, all of which correspond with the sample points 25, 70 and 90 respectively and also coincide with the SARB's downswing business cycle phases. From the high variance regime in credibility reported in the middle panel of Figure 5.2, most of the high volatility in credibility are located between 1990 and 2000, which match the sample points from 20 to 60. The second episode of a high variance regime in credibility is 2005, that is, sample 80, in which the plot shows that policy authority was credible before returning to a low credible policy regime during the financial crisis in 2008. This evidence supports the argument that the SARB did not follow the Taylor-type rule policy during the financial crisis, and instead pursued policy that would stabilise the financial system.

[5] The estimates are transition probabilities not just normal probabilities. According to Khrennikov (1999), probabilities can be negative if a generalization of continuous time Markov chain model with possibly hidden states between two consecutive jumps. This implies that there can be negative transition probabilities for hidden states examine in the case of classical stochastic processes. The model used is characterised by these features.

Figure 5.2: Time-varying smoothed transition probabilities

Note: I encountered modeling challenges and could not capture the years on X-axis instead the observation numbers. Sample points 1=1986:Q1, 20=1990:Q1, 40=1995:Q1, 60=2000:Q1, 80=2005:Q1, 100=2010:Q1 and 120=2015:Q1.



Time-varying transition probabilities for a low and high credibility regimes are shown in the bottom panel of Figure 5.2. This shows that credibility evolves gradually over time. In particular, during the persistence of a low credibility regime, the SARB credibility went up in 1995 and in 2000 prior to explicit inflation targeting regime and then switched from a high credibility regime to a low credibility regime in 2008. After the financial crisis, the low credibility regime was phased out beginning in 2010. The pattern for a low credibility regime is very similar to the pattern of the time series data plot in Figure 5.1. Thus in the middle of the 1980s, economic agents perceived the SARB as being less credible because there were high levels of observed inflation and policy rate, whereas output was low. From 1995 to 2000 and 2003 to 2007, larger credibility losses were minor and short lived, whereas policy credibility gains appear to gather momentum after the global financial crisis.

During a high credibility regime, policy switched from high to a low credibility regime after 1990 and it remained there until 1999. Then, its probabilities peak once again during the Asian crisis in 1998 and the exchange rate shocks in 2001. Following this, the second state switched to a high credibility regime from 2003 to 2007. This coincided with the longest upswings in the SARB's estimated busines cycle phases that lasted approximately 99 months from 1999 to 2007. During the financial crisis, the SARB credibility switched to a low state regime and, finally, moved to a high state credibility regime in 2010. This shows that the financial crisis episode had an adverse effect on the SARB policy credibility, which accounted for cumulative increases in the policy rate of about 5 per cent and inflation peaks at 12 per cent in 2008. This transmits output growth losses, as exhibited in the middle left panel of Figure 5.1.

5.5.2 Generalised Dynamic Responses

The generalised dynamic responses are used to isolate the effects of credibility on macroeconomic performance following a regime change. Figure 5.4 of Appendix C

5.7.2 reports the generalised dynamic responses following a one standard deviation of an unexpected shock to credibility, policy rate, inflation and output. The confidence bands of the dynamic responses are plotted with 95 per cent probability intervals for the posterior densities.

The first panel of Figure 5.4 shows the dynamic responses of credibility to unexpected increases in the other variables. Policy rate reacts countercyclically, leading to a decline in policy rate over the first six quarters. This transmits a reduction in the inflation rate of about 0.1 per cent within the first four quarters. Although real GDP does not response immediately, the uncertainty in real GDP is wide, which suggests that economic agents are uncertain about the sudden gain in credibility by the policy authority. This evidence suggests that it takes time to build credibility, as is argued by Blinder (1999).

In the second panel of Figure 5.4, a positive real GDP shock enlarges uncertainty in policy authority credibility. This means that private agents are uncertain whether policy authority is exploiting the trade-off between output and inflation. Overall, this study has identified that high credibility stabilises policy rate and inflation and helps reduce uncertainty in output growth.

Regarding the third panel of Figure 5.4, a positive unexpected inflation shock generates about 1 percent loss in credibility. This is the largest shock to credibility relative to shocks emanating from the policy rate, as reported in the third panel of Figure 5.4. This suggests that economic agents are more concerned about the fluctuations in inflation and also use the inflation rate changes to measure the level of policy authority credibility in the South African economy. This result is very similar to the findings of Montes (2013), where in an inflation targeting regime, credibility gains affect economic agents inflation expectations which transmit to investment and empolyment decisions. Policy rate responses to inflation shock is about 0.3 per cent. As inflation and the policy rate begin to decrease, policy authorities gain credibility and it peaks in the sixth quarter. However, the signal to the real GDP growth remains uncertain to economic agents.

The fourth panel of Figure 5.4 depicts the dynamic responses of the policy rate shock to the other variables. In this figure, credibility reacts countercyclically to an unexpected positive policy shock. Thus credibility remains constant before it increases during the second quarter, when the policy rate is declining. The unexpected shock in policy rate generates an approximately 0.4 per cent increase in inflation. The effect remains unchanged within the first three quarters before it starts declining in the fourth quarter. In response to this, credibility strengthens in the fourth quarter and leads to an increase in real GDP growth rate. This finding suggests the importance of credibility in the conduct of monetary policy in stabilising policy rate, inflation and output growth. This further implies that a credible central bank needs not adjust policy rate frequently and may require less effort to stabilise the economy.

5.5.3 A Comparison of Monetary and Inflation Targeting Regimes Credibility

Figure 5.5 and 5.6 of Appendix C 5.7.2 compare monetary aggregates regime relative to inflation targeting regime to determine the magnitude of credibility and how it affects policy rate and movements in inflation and output growth. A noticable difference between the two regimes is that the magnitude of inflation and policy responses to credibility is larger over an inflation targeting regime relative to a monetary aggregates regime. This implies that credibility is an important element in the conduct of monetary policy during an inflation targeting regime.

Following a positive, yet an unexpected credibility shock, policy rate declines by about 0.25 per cent, which leads to approximately 0.5 per cent reduction in inflation over the inflation targeting regime, as reported in Figure 5.6. On the contrary, a similar change in credibility over a monetary aggregates regime accounts for less than 0.1 per cent reduction in the policy rate and inflation, as shown in Figure 5.5. Similarly, a positive policy shock to credibility in an inflation targeting regime results in an immediate loss of credibility of about 0.5 per cent but remains muted in a monetary aggregates regime at the initial stage before improving marginally. Moreover, a one standard deviation from inflation generates about a 1 per cent loss in credibility in an inflation targeting regime whilst this accounts for less than 0.5 per cent in a monetary targeting regime. This clearly shows the importance of credibility over the inflation targeting regime relative to the monetary aggregates regime.

What is not surprising is that uncertainty in policy setting was predominant in the monetary aggregates regime, as reported in Figure 5.5. This confirms that if all things remain the same, the inflation targeting regime helps anchor inflation and output volatility and serves as a catalyst for efficient policy rate setting.

This study certainly shows that the most relevant factor driving inflation and output deviation is credibility. It is concluded, therefore, that credibility is one of the most canonical toolkits that a central bank must possess in the conduct of monetary policy over an inflation targeting regime. Without credibility, it will be less possible for the policy authority to deliver on its policy objectives.

5.6 Conclusion

This chapter evaluates central bank credibility and its effect on the policy rate, inflation and output growth before and after the adoption of a new monetary policy regime. The question is important in the light of current events, where policy authorities have deviated from following their committed policy objectives relative to unconventional monetary policy. This has been strongly criticised by some economists and the general public because economic agents lose confidence in such events in the conduct of monetary policy. In doing this, a Markov-switching Bayesian VAR with time-varying transition probabilities is used. This is a unique way of allowing the belief structure of credibility to evolve over time. South African quarterly data covering the period 1986:Q1 to 2016:Q3 are used.

The results suggest that the smoothed transition probabilities in means and variances of credibility index evolve gradually and are unstable over the sample period. This study tracks the major periods in which the SARB gained and lost credibility. The results suggest that these coincide with the business cycle phases in the South African economy. A distinctive pattern between monetary aggregates and inflation targeting regimes is that the degree of inflation and policy rates reaction to credibility shocks is larger in the latter relative to the former. Although in the monetary aggregates regime, credibility behaves well and mostly remains within the credibility threshold of 1 and 0, uncertainty surrounding credibility was high relative to inflation targeting regime.

To sum up, it is found that credibility significantly influences changes in macroeconomic fluctuations. This means that credibility should be one of the key tools that policy authority should possess in the conduct of monetary policy in an inflation targeting regime. Without it, policy authority may find it less possible to achieve its policy objectives. It would be interesting in future research to examine financial and fiscal stability variables on credibility to gain a broader understanding of the dynamics of credibility in an inflation targeting regime.

5.7 Appendix C: Chapter 5

5.7.1 Diagnostic Tests

Table 5.3: Unit root tests

series	Lag	ADF Test	PP Test	1% crit. val.	5% crit. val	10% crit. val.	P-value
Cred. Ind.	Level	-3.88	-3.62	-3.49	-2.89	-2.58	0.007
Inflation	log diff.	-5.39	-5.42	-3.49	-2.89	-2.58	0.000
Policy Rate	Level	-1.79	-1.50	-3.49	-2.89	-2.58	0.530
Real GDP	log diff.	-6.47	-6.69	-3.49	-2.89	-2.58	0.000

Source: Author's estimation March 17, 2017

Table 5.4: Johansen's cointegration test

Rank	Eigenvalue	Likelihood ratio	P-value	5% critical val.
R=0*	0.18	-458.55	-0.023	47.86
$R \leq 1$	0.11	-458.55	0.094	29.79
$R \leq 2$	0.08	-451.78	0.089	18.49
$R \leq 3$	0.03	-446.78	0.052	3.84

**denotes rejection of the null hypothesis at* 0.05% *significance level, P-values obtain by Mackinnon (1999) one sided p-values*

Table 5.5: Granger causality tests

Null Hypothesis	Obs	F-statistic	Prob.
Policy rate does not Granger cause credibility	121	2.93	0.06
Credibility does not Granger cause policy rate		1.72	0.18
Inflation does not Granger cause credibility	121	0.48	0.62
Credibility does not Granger cause inflation		4.63	0.01
Real GDP does not Granger cause credibility	121	0.94	0.40
Credibility does not Granger cause real GDP		0.56	0.57
Policy rate does not Granger cause inflation	121	4.42	0.01
Inflation does not Granger cause policy rate		0.98	0.38
Real GDP does not Granger cause policy rate	121	1.61	0.21
Poicy rate does not Granger cause real GDP		0.95	0.39
Real GDP does not Granger cause inflation	121	0.05	0.95
Inflation does not Granger cause real GDP		4.20	0.02

Source: Author's estimation March 17, 2017. Note: the optimal lag is 2.

5.7.2 Estimated Results

Figure 5.3: Posterior densities

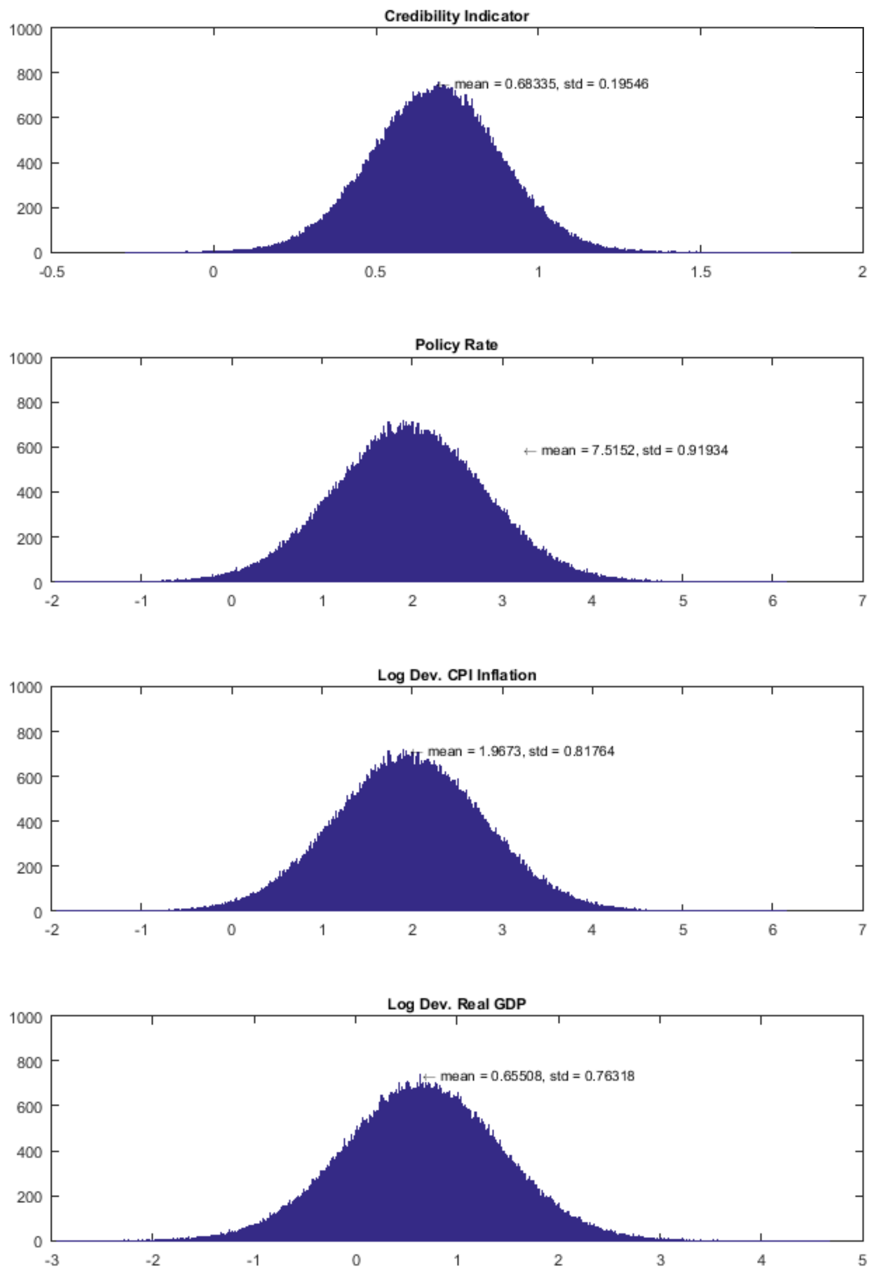


Figure 5.4: Generalised dynamic responses—full sample

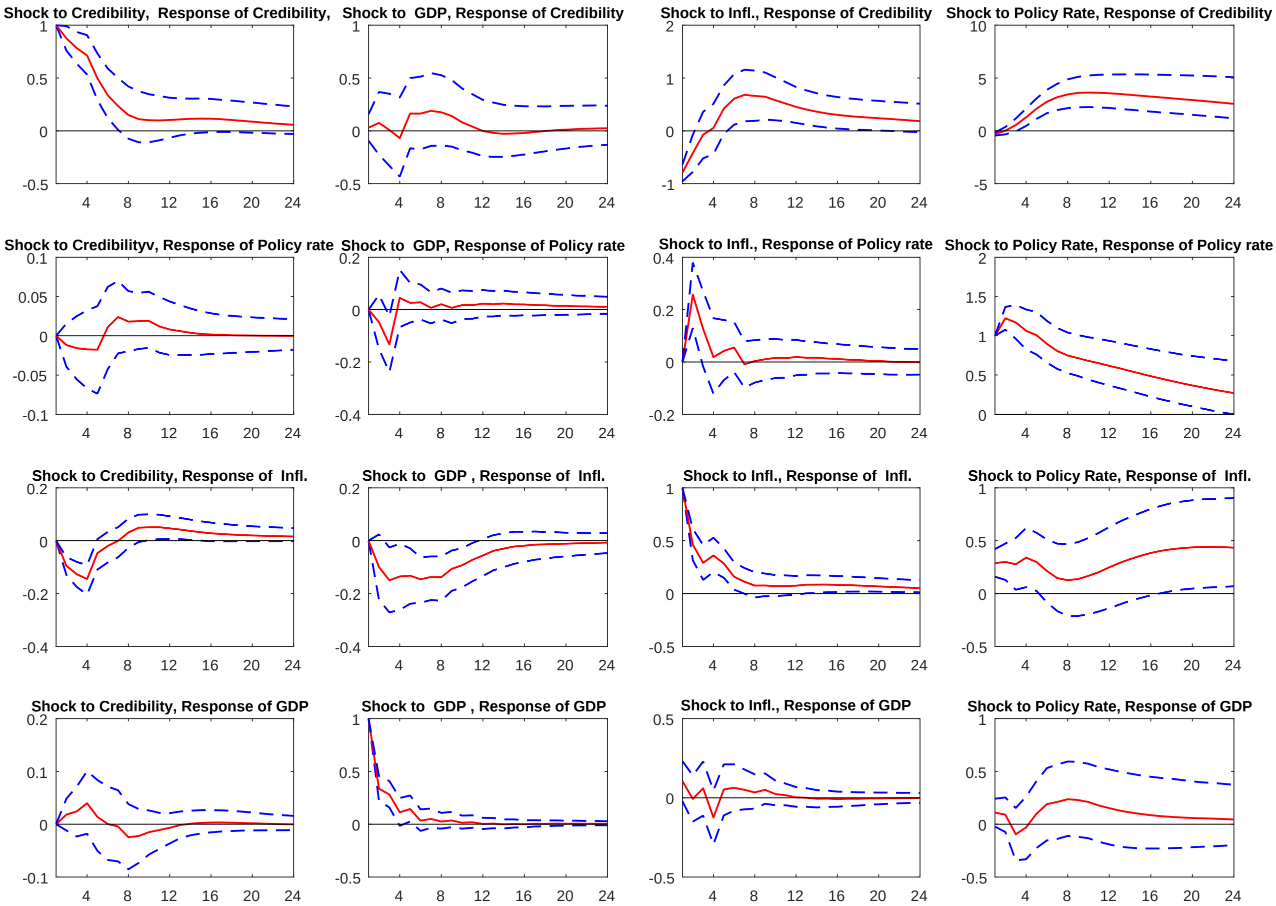


Figure 5.5: Monetary aggregates regime generalised dynamic responses

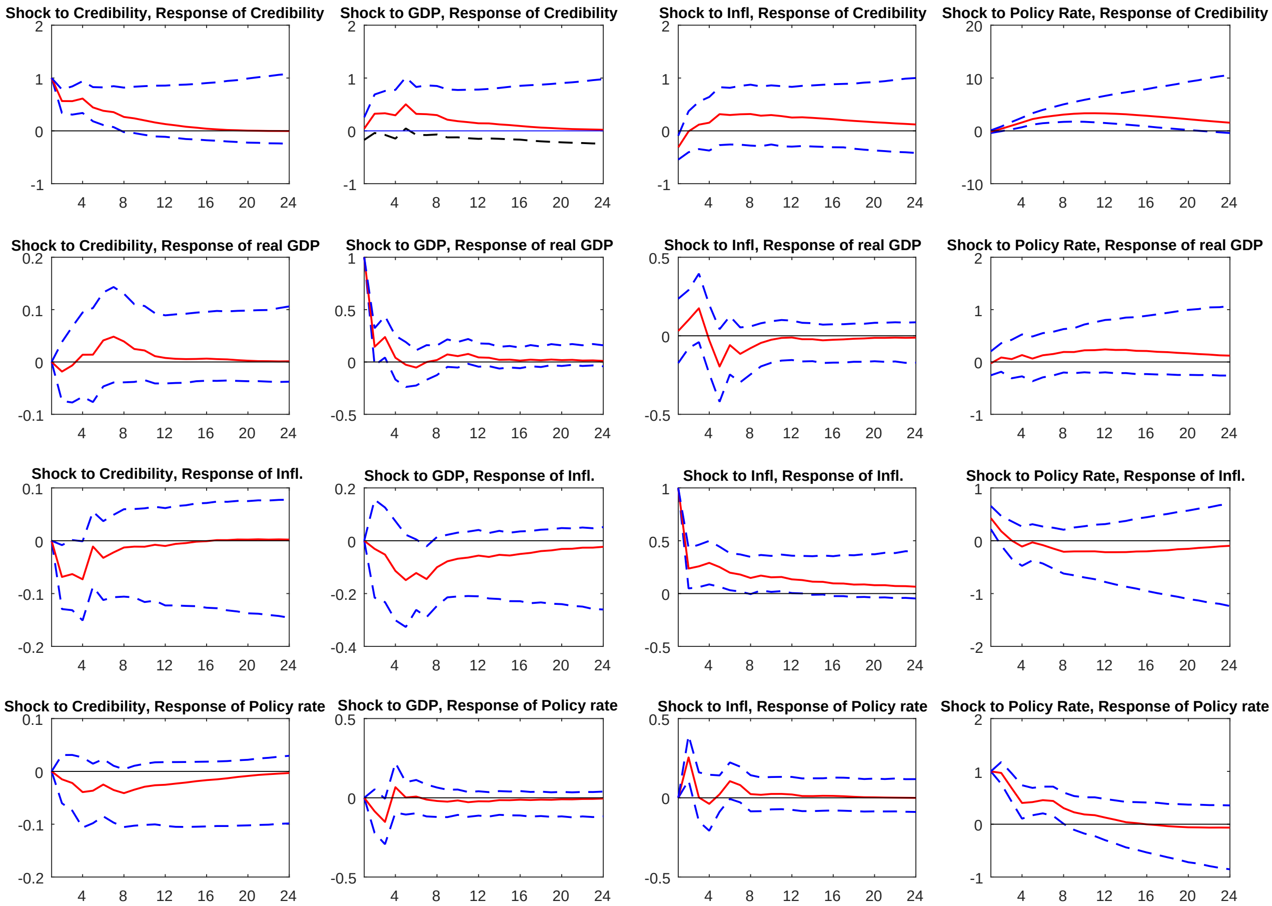
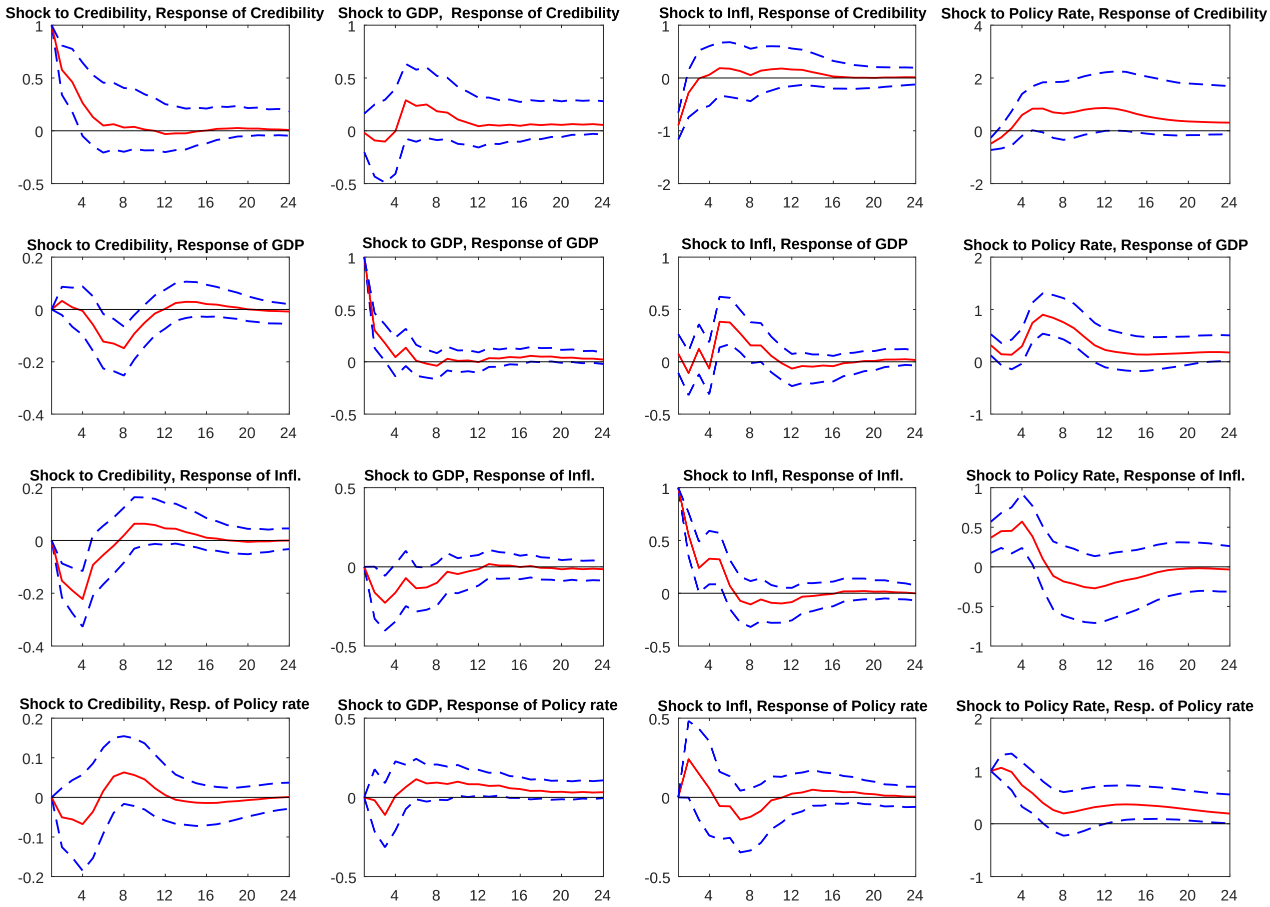


Figure 5.6: Inflation targeting regime generalised dynamic responses



Chapter 6

Conclusion

6.1 Summary

The purpose of this thesis has been to evaluate the extent of macroeconomic dynamic responses to changes in policy regimes based on the proposition that the Taylor-type rule better anchors inflation and output volatility. Chapter one motivates and positions the themes presented in the thesis within the literature. This is followed in chapter two by a comprehensive review of monetary policy regimes in the South African economy, thereby providing nuances for the empirical estimations that follow.

Chapter three analyses policy regime changes in relation to policy authority preferences and looks at whether a particular central bank governor's term is linked to policy authority preferences. A time-varying vector autoregression is used to capture the changing policy preferences and shocks. The main contribution of this chapter is that it examines the importance of changes in policy preferences and shocks and its effect on inflation and output in a way that is different from studies that analyse the reaction of policy shocks on the economy only. Moreover, two solution methods are initiated. These are the Kalman filter and independence Metropolis-Hastings. The Kalman filter is used to obtain the weights a policy authority attaches to inflation and output, whereas the independence Metropolis-

Hastings estimates the generalised impulse responses and stochastic volatility in a time-varying parameter setup. The relevance of this chapter includes, first, that it shows that at different times and over different monetary policy regimes the economy reacts differently to policy preferences and shocks. Secondly, the chapter extends current research of policy regimes in the South African economy where the analyses are restricted to traditional econometric methods, such as OLS and the generalised method of moments. Finally, the counterfactual effects of how policy would have been without changes in central bank governors, policy regimes and the responses of the South African Reserve Bank to the recent global financial crisis are examined.

The findings in chapter three suggest that policy changes have an important effect on the weight a central bank attaches to inflation and output stability, and governors' preferences are linked to policy regime changes. This implies that the beliefs of central bank governors should align with the policy regime in place at the time of their appointment. The usefulness of this chapter is that it shows that changes in central bank preferences are influenced by changes in monetary policy regimes and not necessarily the tenure of different governors at the central bank. Furthermore, the counterfactual analysis shows that the responses of the global financial crisis would have been larger on the economy had the South African Reserve Bank not reacted. Similarly, the weights attach to policy preferences without a regime change would have been similar to an inflation targeting regime with a smaller deviation, which presupposes that structural shocks play a role in stabilising the economy over the inflation targeting regime.

Chapter four evaluates the reaction of policy regime-switching on macroeconomic performance to identify whether the South African economy is characterised by policy switches. This responds to the role played by policy preferences and shocks on changes in inflation and output volatility in a structural model. A Markov-switching dynamic stochastic general equilibrium model is used and the model is estimated by an efficient perturbation method, which allows for a single equilibrium condition relevant for economic analysis.

This chapter contributes to the literature by allowing the primary commodity export sector shocks to depend on regime switches. The importance of this is that it explains the effects of policy regime switches in emerging economies that depend on primary commodity exports. This is relevant, because one of the factors that influence slow economic growth in emerging economies is a decline in world demand for their primary commodities and also a decline in primary commodity prices. It is found that policy shocks have minimal effects on macroeconomic volatility when the structural innovations are accounted for in a regime-dependent analysis. This thesis also establishes that volatility in the structural innovations outperform constant dynamic stochastic general equilibrium model.

Further, the policy rate reaction in an inflation targeting regime is much larger compared to a monetary aggregates regime. Whereas in a monetary aggregates regime, an export shock to policy rate responses is larger relative to that in an inflation targeting regime. This suggests that in an inflation targeting regime low export shock volatility helps in stabilising inflation and output volatility prior to the global financial crisis. It is, therefore, proposed here that policy evaluation based on constant dynamic stochastic general equilibrium models should be used sparingly to draw conclusions on recent macroeconomic fluctuations in emerging economies because of changes in the shocks volatility that affect the economy.

In chapter five, the responses of central bank credibility to macroeconomic fluctuations when there is a policy regime change are investigated. The unobservable dynamics of policy authority credibility over time is estimated using a Markov-switching Bayesian autoregression with time-varying transition probabilities. The reason for this is that there is no consensus on whether central bank credibility is enhanced when policy authority adopts a new policy regime. Secondly, the South African Reserve Bank switched it inflation target from the consumer price index excluding mortgage interest cost to the overall consumer price index, something which is likely to undermine the Bank's credibility. This chapter responds to these issues to understand how macroeconomic variables react to policy authority credibility and also allow the data to assign the switches in credibility instead of the researcher.

Finally, it is found in chapter five that credibility positively affects changes in macroeconomic fluctuations. Therefore, credibility should be one of the canonical instruments that a policy authority must possess in the design of monetary policy. This finding is of particular policy relevance in the ongoing debate about whether the unexpected changes in macroeconomic volatility will persist, given the unconventional monetary policy practice in developed economies and weak economic growth recorded in emerging economies.

6.2 Future Research

This thesis has shown empirically that policy regime changes are necessary to stabilise inflation and output in an economy. However, there are other aspects of policy regimes that this thesis could not address that needs further research. In chapter three a backward-looking time-varying policy regime is analysed. It would be important to examine a forward-looking time-varying policy regime both with and without the policy rate smoothing to understand monetary policy as an inflation forecasting regime. This will help to track a policy regime in accordance with the tenets of an inflation targeting regime to ensure effective central bank accountability and credibility to economic agents.

The limitation of chapter four is that the transition probabilities are constant over time, which may require a new estimation strategy to endogenised it in future work. Finally, in chapter five, the effects of financial stability and fiscal policy on central bank credibility were not investigated. This could be examined to broaden the understanding in this area in future research.

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